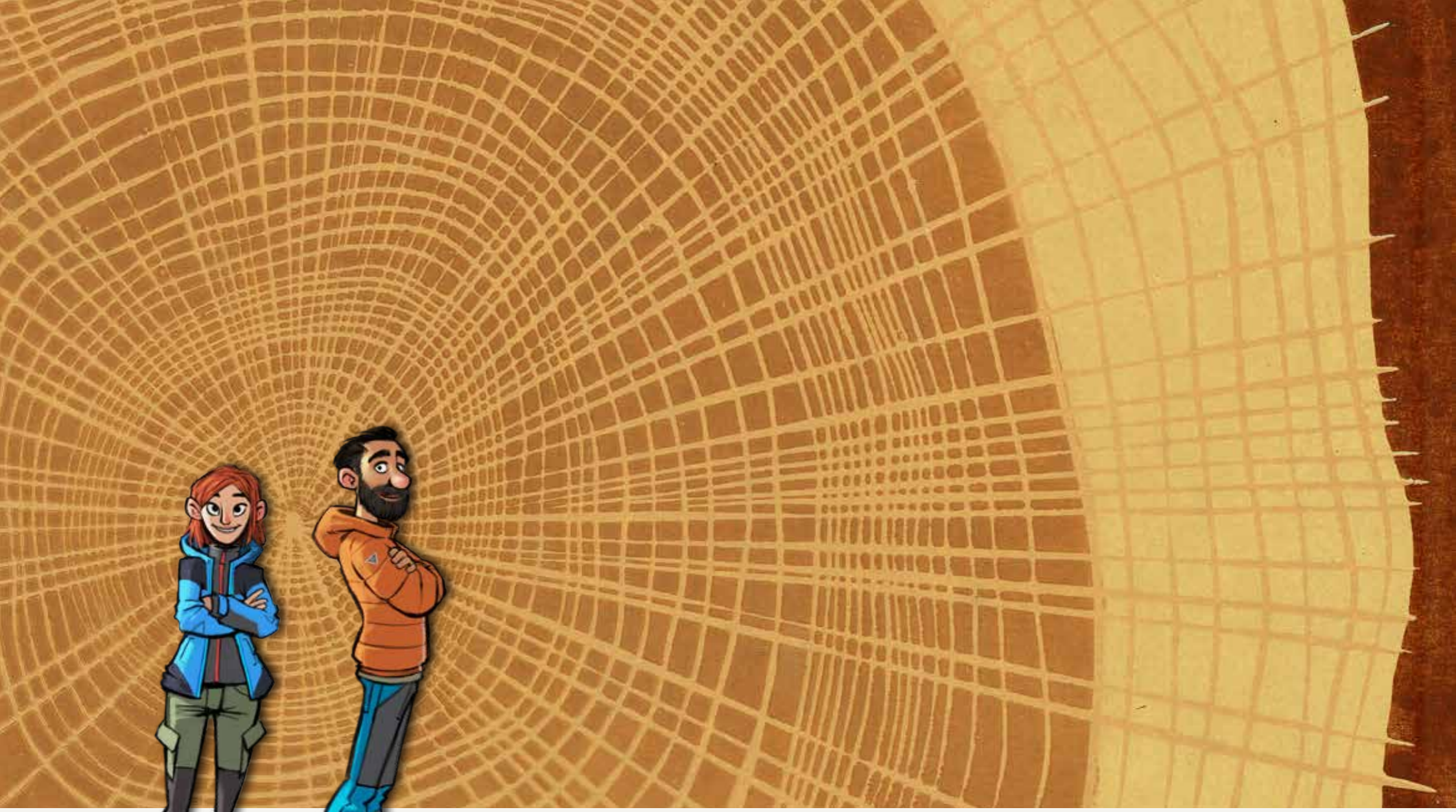

Dendrochronology

Explore the science of tree ring dating

"I never cease to be amazed that dendrochronology works as it does. Oak trees should not exhibit such consistently similar ring patterns, but they do."

Mike Baillie, *Tree-ring dating and archaeology* 1982, 25.

Acknowledgements

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Dendrochronology

Explore the science of tree ring dating

Marcia Cook, Coralie Mills and Jennifer Thoms

Contents

Introduction

Trees form a living record of seasons and time, often stretching beyond generational memory. Individual trees can be hundreds of years old, and by cross referencing their individual tree ring patterns we can reach back even further. This is the science of **dendrochronology**.

This booklet aims to help teachers and youth group leaders use dendrochronology as a cross-disciplinary classroom topic as part of the **Curriculum for Excellence**, blending history, science and mathematics. Join our intrepid dendrochronologists Danny and Donald in learning about the history and science of tree ring dating, and explore the principles of dendrochronology through three supporting activities:

- **The Tree Core Sample** introduces how tree rings grow and how the science of dendrochronology uses the pattern – or *sequence* – of this annual tree ring growth to investigate the past (to be undertaken individually or in pairs).
- **The Tree Ring Chronology** involves the class building a short timeline or simple *tree ring chronology* of one hundred years using *tree ring sequences* (to be undertaken in teams).
- **The Reference Chronology** sees the class build a long timeline or *reference chronology* of over one thousand years and then use it to date a range of archaeological samples (to be undertaken first individually and then as a class).

The activities gradually build on one another, but each can be used in isolation if the principles of tree ring growth are firmly understood. The activities are most suitable for learners at Second Level and above.

Four short articles explore the practice of dendrochronology, investigating building timbers from Stirling Castle, the archaeological excavation of waterlogged timbers at Buiston Crannog, the dating of museum artefacts with the Hamilton Palace Capitals, and the exploration of woodland heritage in Dalkeith Park.

"Archaeology is the study of the human past through its material remains. Through archaeological research and analysis of our places, artefacts and ecofacts, everyone can explore, better understand, value and care about the prehistory and history of Scotland's people, culture and landscape."

Scotland's Archaeology Strategy 2015.

In engaging pupils in outdoor learning and conducting meaningful research within the classroom, archaeological learning can provide real and cohesive links across a range of curricular areas.

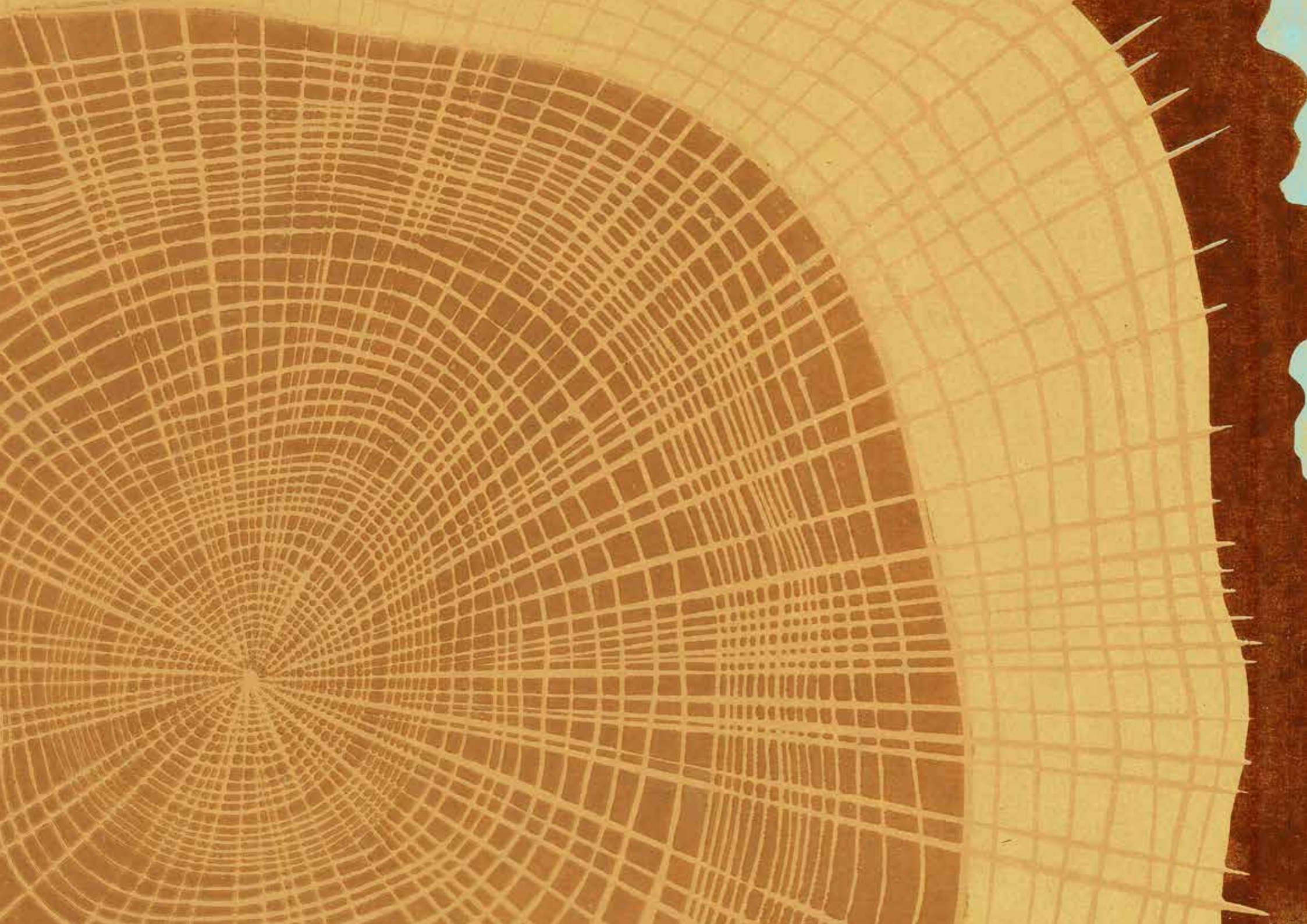
Archaeology is the study of the human past through its material remains, interpreting objects and structures recovered by excavation and investigation, and history is the study of the human past through documentary and archival research, explaining actions through words and pictures on the page or on the wall, and now even on the screen. Although archaeological techniques can be applied to the study of all periods in time, there is a significant difference between archaeological interpretation and historical evidence. However, the connections that can be made between archaeological discovery and historical text improve with greater precision in archaeological dating. Many historical texts have specific dates to a year, and the ability to date material culture remains to a specific year through dendrochronology allows archaeological and historical records to be directly compared.

"Dendrochronology is probably the asset that will do most to invite archaeology on to the high table of history."

Martin Carver, *Archaeology with Texts* in *Archaeology: the widening debate* 2002, 481.

Danny uses a power drill with a special *core drill bit*. This enables her to extract a long thin core from a historic building timber.

Donald has been busy preparing the sample he took from the oak tree. He first had to allow the unseasoned timber to slowly dry out, binding it to the mount so that it didn't warp. Then he carefully glued it onto the mount and sanded its surface with ever finer grades of sandpaper. Now he can measure the rings under the microscope.



What is dendrochronology?

The words *chronology* and *dendrochronology* are derived from ancient Greek: 'dendros' meaning 'trees', 'chronos' meaning 'time' and 'ology' meaning the study of something. A *chronology* refers to a sequence of past events, while the science of *dendrochronology* uses the annual growth rings laid down by trees to characterise and date timbers.

We are going to focus on the applications of dendrochronology in archaeology, and in the study of historic buildings and ancient woodlands. But there are many other fields of application for dendrochronology, including climate science and the geosciences (dating landslips and earthquakes for example). It is also used in ecology to look at woodland dynamics, and in forestry to study timber growth rates.

◄ **Oak has a pale *sapwood* and a dark *heartwood*, and distinctive *medullary rays*, running at right angles to the rings from the centre of the trunk towards the bark edge.**

Tree ring sequences

A tree ring is the layer of *xylem* cells produced in one year. *Xylem* cells form the wood in the tree. In 'ring porous' trees like oak a single annual tree ring comprises both the paler ring known as *earlywood*, which is formed in the spring, and the darker ring known as *latewood*, which is formed at the end of the growing season. Together, the *earlywood* and *latewood* form one annual ring which usually extends around the entire circumference of the tree. The new ring is formed just under the *bark*, by the *cambium* layer which grows the new cells. The inner facing side of the *cambium* layer produces the *xylem* vessels and the outer facing side produces the *phloem* cells which form the tree's *bark*.

There are two different types of wood within the tree. The thinner outer *sapwood* layer is made of the newer *xylem* cells. The *sapwood* carries water from the tree's roots to its leaves. The thicker inner *heartwood* is made of old *xylem* cells and can be found surrounding the *pith* at the centre of the trunk. It no longer carries water but supports the weight of the tree and is filled with resins that resist decay. Simply stated, the most recently formed tree ring is just under the

bark, and the rings get progressively older towards the centre of the tree.

The width of the ring depends on the growing conditions for that year – the better the conditions, the wider the ring will be, while in a poor year for growth, the ring will be narrow. In this way a pattern of wide and narrow rings builds up in the tree, representing the growing conditions for that period and place. Other trees of the same species, growing in the same wood at the same time, will have a similar pattern or *sequence*, although they will not be absolutely identical (as every tree is unique).

- The annual growth pattern of tree rings is known as a *tree ring sequence*.

This representative pattern happens most reliably in the temperate parts of the world, where the seasonal differences are most pronounced. A *tree ring chronology* can be built by matching and overlapping the *tree ring sequences* of many different trees over time and combining their data.

◄ **Conifers like Scots pine have a different wood structure than broadleaf trees, and lack the *medullary rays* that are so distinctive in oak. The ring pattern is usually quite clear in conifers, but different species of coniferous wood are hard to tell apart except under the microscope.**

Tree ring chronologies

Building a *tree ring chronology* requires a lot of hard work – and a lot of samples from the chosen tree species. In Europe, oak is one of the most common timber types used for dendrochronological dating. Many tree species have a different appearance between the inner *heartwood* and the outer *sapwood*. Oak is one of these species, and it also has a predictable number of *sapwood* rings; there are usually a minimum of 10 and a maximum of 55 *sapwood* rings present on British oak. This is known as the *sapwood* range. When a timber lacks its bark edge, and some of the outer *sapwood* rings may be missing, it may still have some *sapwood* left. This allows the date to be estimated of when the tree was cut down. Dendrochronologists call dates like this a *felling date range*.

> *"Consider the medieval builder who cannot read or write. He fells an oak and uses its timber in some construction. The builder we will never hear from again, but that oak can for ever more tell us the exact date of its last year of growth. Curious isn't it, that the oak has been given this gift of immortality?"*
>
> **Mike Baillie, *Tree-ring dating and archaeology* 1982, 25.**

Oak timber is also reasonably easy to identify with the naked eye. It has a pale *sapwood* and a dark *heartwood*, and distinctive *medullary rays*, running at right angles to the rings from the centre of the trunk towards the *bark* edge. The difference in colour between the *sapwood* and the *heartwood* is a very strong feature in oak – as are the *medullary rays* – and help identify oak timber in old buildings and on archaeological sites without needing microscopic analysis of the wood anatomy.

- Use the oak timber illustration to discuss this anatomy – your learners may then be able to recognise oak timber themselves, from fallen trees in the woods through wood drying (or seasoning) in the woodpile to timbers within historic buildings.

So, a simple *tree ring chronology* can be built using lots of samples – both from living trees and from old timbers – as long as they are from the same tree species and the same region. In Scotland, it is also possible to date native Scots pine based on the recent development of a network of regional *tree ring chronologies* for pine. Occasionally other tree species are analysed, but oak and pine are the main two tree types worked on in Scottish dendrochronology.

- A *tree ring chronology* is a simple timeline built by cross-dating, matching and overlapping the annual *tree ring sequences* of different trees from the same place over time.

The first dendrochronologist

Andrew Ellicott Douglass (1867-1962) founded the scientific discipline of dendrochronology in America. Douglass was an astronomer studying sun spot cycles and their effect on our planet's climate. While other scholars had recognised the annual nature of tree ring growth, it was Douglass who developed the scientific technique of cross-dating and realised the potential for building long chronologies from tree rings.

Douglass did not come to tree rings with the idea of developing a dating method for archaeologists. He was more interested in climate. The climate records where he lived in Arizona were very poor, so he looked to tree rings to help him. In the stable semi-arid environment of the American south west, the tree ring records enabled him to reconstruct rainfall variations over time – it was easy for him to distinguish between the thin rings produced in dry years and the thick rings produced in wetter ones.

Douglass' initial work was on Yellow pine, but they were limited to about 500 years in age, so he took an interest in the giant redwoods of California, which can live for around three thousand years (the oldest known redwood is over 3500 years old). By 1919 Douglass had built a Redwood chronology stretching back 3221 years.

But there were some problems with the Redwood sequences, with some missing rings, and so Douglass returned to Yellow pine, building a chronology stretching back to AD 1284. Douglass had been using natural timber (both alive and dead) but he soon realised that he could extend the Yellow pine chronology with timbers from ancient ruins in the area.

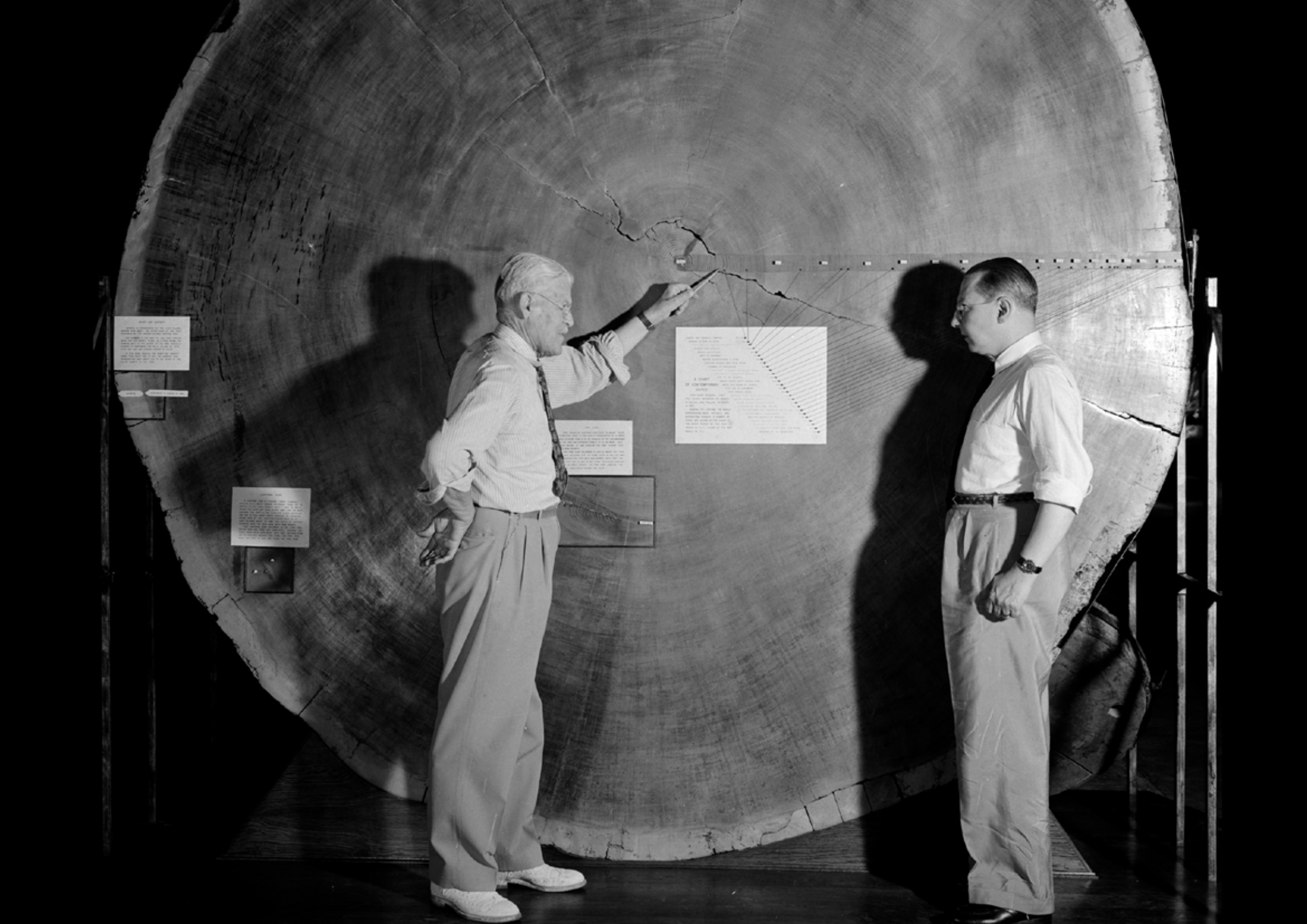
At first, he built *floating chronologies* – groups of *tree ring chronologies* not pinned down in time – but over many years of fieldwork he found the bridging material, and eventually connected the natural and historic chronologies to make a long *reference chronology* reaching back to AD 701. In doing so he had created the first cross-dating method and had laid the foundations of the science of dendrochronological dating that we use today.

- A *tree ring chronology* is a simple timeline built by cross-dating, matching and overlapping the annual *tree ring sequences* of different trees from the same site (or place) over time. This is also referred to as a site chronology.
- A *floating chronology* is an individual or group of *tree ring chronologies* not yet fixed in time – we don't know any exact dates on the timeline.
- A *reference chronology* is built from lots of different *tree ring chronologies* now fixed in time – we now know the exact dates on the timeline.

The principle of cross-dating was established by Douglass, who used it to extend his chronologies back before the limits of living trees. The principle states that by correctly matching patterns among several *tree ring sequences*, it is possible to identify the exact year in which each tree ring was formed. So we can date the construction of a building by matching the pattern of the *tree ring sequence* of wood taken from the building with the pattern of the *tree ring sequence* in the regional *reference chronology*.

The giant sequoia

For many years one of the most memorable attractions at the Arizona State Museum was a large cross-section of a giant sequoia, prepared so that the rings were visible and marked with the dates of various historical events. In this photograph, Andrew Douglass is seen pointing to rings formed early in the life of the tree, in the 3rd century AD. A list of historical events is below his hand, with each date tied to the corresponding tree ring by pins and a length of string. Immediately in front of him another label identifies an event which was significant for the tree itself: a forest fire that injured it, leaving a scar visible in the pattern of rings. (Arizona State Museum) ►



The longer the overlapping period, the easier it is to bring together samples into a *tree ring chronology* and the easier it then is to fit the *tree ring chronologies* together into a *reference chronology*. When dendrochronologists are building new chronologies, they prefer to work with long *tree ring sequences*, ideally over 100 years. However, historic and archaeological material isn't always so long-lived, and shorter *tree ring sequences*, sometimes down to 50 years, can be used when doing dating projects. The longer the overlap, the easier it is to find the correct position of match (and there is special computer software to help the process). *Tree ring sequences* of less than 50 years in length are too short to be used (the activities in this learning resource use shorter lengths to make them easier to deliver).

Regional reference chronologies

We now understand that there are many environmental and climatic processes that can affect tree ring growth. Plant growth is most constrained by the primary environmental variable that is most limiting on growth – the *limiting factor*. A plant could be too hot or too cold, too wet or too dry. For example, rainfall is the most limiting factor to plant growth in arid and semi-arid areas – growth cannot proceed faster than the growth that is allowed by the amount of rainfall a plant receives. In trees growing in hot, dry semi-arid conditions (like in Arizona), a dry year produces a narrow ring and a wet year a wide ring. But what happens if it is dry all the time (in arid areas such as those in the south of Europe) or wet all the time (such as the Atlantic rainforests of the west coast of Scotland)?

Dendrochronologists must then look for a different *limiting factor*. In higher latitudes and elevations, temperature is often the most *limiting factor*, such as with Scots pine in Highland Scotland, where high-altitude pines reflect summer temperature records reasonably well.

For many woods, climatic factors may not be the most *limiting factor* on tree growth, and certain local dynamics within the woodland may be more influential (such as competition for light or nutrients), or human disturbance (such as felling or coppicing). An individual tree's growth can be influenced by a number of local environmental factors, both human and natural, over time – and the relative influence of the different factors may vary from year to year.

Understanding the principle of the *limiting factor* is especially useful in selecting the right woodland sites for dendrochronological research – and it's really important for the dendrochronologist to be able to sample as many trees as possible when they build their *tree ring chronology*. They can then start to smooth out any individual *limiting factors* that may have affected an individual tree's tree ring growth (known as *noise*) and see the bigger picture for the whole wood (known as the *signal*).

Tree ring sampling methods

It is possible to sample living trees for dendrochronology using an *increment borer*. Obtaining living tree samples often forms the first stage of developing a regional *reference chronology*, although fallen deadwood can also be sampled by taking slices. Timbers in old buildings are usually cored using special coring bits driven by a power drill. If timbers are being removed from the building, or the building is being demolished, then it is also possible to obtain slice or disc samples, either hand sawn or taken with a chainsaw.

Archaeological wood, which is usually only found preserved in waterlogged sites, is sampled by taking slices. This type of sample requires environmentally controlled cool storage, or storage in water or gel-filled tanks, to prevent decay.

There is often a mix of sample types in any dendrochronological project, from cores taken from living trees, discs cut from fallen trees, timber cores taken from historic buildings– even impressions taken from *in situ* building timbers and photographs of *tree ring sequences*.

A Dendrochronologist's Equipment

- **Ordnance Survey maps**
- **Notebook**
- **GPS**
- **Measuring tape**
- **Increment borer**
- **Unjamming kit (a hammer, a rifle cleaning kit and a plastic golf tee – to get stuck bits of tree core out of the borer without damaging it)**
- **Power drill with core drill bit**
- **Pocket knife**
- **Folding saw**
- **Flask**

Dendrochronological jigsaw puzzles

Dendrochronology can be thought of as an interconnected series of jigsaw puzzles, some large and some small, some local to a wood and some crossing borders. Each jigsaw puzzle is unique – but the more of each jigsaw puzzle that is complete, the easier it is to see the bigger picture.

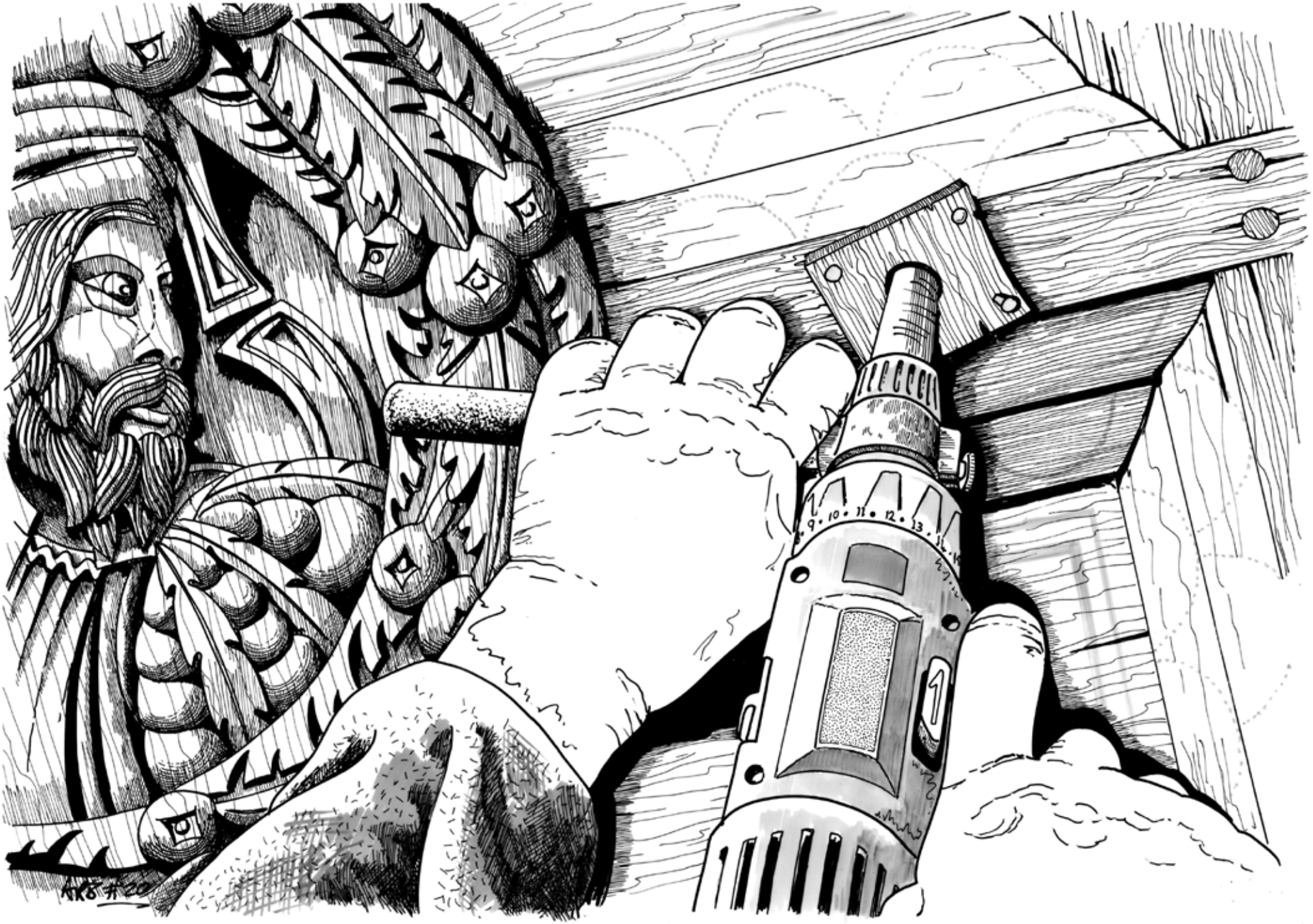
Over the last few decades, dendrochronologists working in Scotland have analysed samples from many individual sites, including a range of historic buildings, archaeological sites and old woodlands. While the work to develop our own native regional *reference chronologies* is ongoing, and many pieces of its jigsaw puzzle are yet to be found, a bigger picture does emerge when we bring these results together – a story of the character and fate of Scotland's woodlands and the development of a timber trade.

For the last millennium or so, we do have quite a lot of Scottish data, for both native oak and native pine, which allows us to date and provenance home-grown oak and pine timbers. Dendrochronological study of historic woodlands has found out just how old some of our oldest trees are, with oaks at Cadzow near Hamilton dating as far back as the 15th century – and some ancient pine trees in the Highlands originating in the middle of the 16th century. These ancient trees provide really valuable *tree ring sequences* used to build our own network of *reference chronologies*.

Looking outside Scotland, there is an even larger set of *reference chronologies* available from other countries, especially across Northern Europe and Scandinavia, for both oak and pine. This has allowed us to identify examples of imported timber in Scotland. Importing timber starts to occur surprisingly early, in the medieval period, but this was balanced with home-grown timber.

From about the middle of the 15th century, the majority of dendrochronologically dated structural timbers have been identified as being imported, coming first from Scandinavia and then later from further east in the Baltic region. There was also a specialist medieval trade in oak boards from the eastern Baltic for decorative carving. The technique of identifying the source of timbers through their *tree ring sequences* is known as *dendro-provenancing*.

The dendrochronological evidence shows that Scotland was running short of decent home-grown timber by the late medieval period, and had increasingly turned to importation. The worsening state of our woodlands was eventually recognised by the authorities in late medieval times and Acts of Parliament were passed in Scotland to require landowners to protect woods and plant trees, but this had little overall effect on timber supply. However, there are some biases in our data, because most of the dated buildings are near the east coast or in the central belt where it was easier to access imported timber, and we still need to develop the native *reference chronologies* for many other regions – piecing together more of the great dendrochronological jigsaw puzzle.



Dating the timbers from Stirling Castle

As well as a helpful dating tool, the study of tree rings can be used to determine where wood has come from. Scientific dating techniques such as dendrochronology can help archaeologists verify and build upon historical documents. Work at Stirling Castle is a great example of how archaeologists were able to expand on historical data and also learn more about trade and the natural environment in late medieval Scotland, Scandinavia and Europe.

Analysis of oak beams in the Renaissance Palace at Stirling Castle, provided evidence for four periods of construction in the 16th century, starting in 1539. It was found that older wood, recycled from other buildings constructed only 34 and 38 years earlier, was used when building the palace.

The ceiling of the King's bedchamber, a very important room, was partly built using recycled timber. The recycled timber was found to have grown in Scotland, and was some of the very small amount of native wood found in the samples taken from the Palace. This reflects a shortage of suitable woodland in Scotland at the time – good quality timber from large, mature oak trees was a rare and precious resource. We know that parliament passed Acts to encourage the conservation of woodland and the planting of new woodlands. Most of the other oak beams were found to have been imported from Scandinavia.

Oak was also used for making boards, for doors, and for decorative carvings known as the Stirling Heads. Fine, straight-grained timber was valued for carving and this wood was sourced from the southern and eastern Baltic region, and particularly from Poland. The oak at Stirling Castle shows that the Scottish royal household could access trading links across Europe and Scandinavia which let them overcome the lack of good native oak timber at home.

Pine timber was also analysed at Stirling, and studying the *tree ring sequences* revealed two more periods of building activity in the Palace – this time in the 17th and 18th centuries. The work also revealed that the pine ceiling above the Queen's bedchamber, previously thought to be a later addition, was in fact an original 16th century feature put in when the Palace was first built.

The pine used in the 16th and 17th centuries came from southern Scandinavia, and was probably imported as boards and beams (and not as raw timber), as saw-milling was not widely adopted in Scotland until the 17th century. In the 18th century the pine used came from the Baltic region, and, like the oak, could have come from anywhere within the huge hinterland of forest, the timber being transported down the rivers by being fastened together into rafts. Pine was used because, by the 17th century, oak was becoming scarce even in Scandinavia.

The Tree Core Sample

This introductory activity explains the principles of tree ring dating and could be used to enable a class to subsequently investigate a real tree trunk section. This activity uses an imaginary thirty-year-old oak core that can be printed for classroom use. This activity should be done individually or in pairs.

One tree ring equates to one year of seasonal wood growth. Trees grow outwards from under the bark layer and the newest wood ring is closest to the outer edge of the tree's circumference. By felling or coring a tree, this growth pattern – known as a *tree ring sequence* – can be measured and studied. Dendrochronological coring methods allow the study of a tree's rings by taking a sample for investigation, allowing the tree to continue growing.

The activity explores the tree's annual growth rings and how variation in ring sizes is related to growing conditions. The rings are investigated through measurements, which are used to produce a representation of a dendrochronological core – the **tree ring recording strip**.

The tree ring recording sheet

A simple tree core has been illustrated for study. The darker lines represent each new tree ring. The lighter background lines are divisions (presented at a scale of 2:1) to help learners with ring measurements. A good starting point would be to make a count of the rings to establish how old the tree was and discuss the mechanisms by which each layer of new wood is added to the tree. Finding examples of real tree stumps for study in the local woods or parks and counting their rings will reinforce this learning.

Once the ring count is made successfully, and the principles of tree ring growth have been explored, the science of dendrochronology can be introduced by measuring the width of the rings. Count the divisions between each darker ring and record this number in the **sequence table**.

- Remember, the thickness of each annual tree ring indicates the growing conditions at that time – taken together they form a unique *tree ring sequence*.

The tree core has a scale of 2:1 to introduce learners to the 2:1 scale used by the **tree ring recording strips**. The background lines on the core have been set 2 mm apart but each represents 1 mm of tree ring growth in real life.

The tree ring recording strip

Using the numbers recorded in the **sequence table**, ask your learners to carefully draw each ring line onto the **tree ring recording strip** to create their very own illustration of a tree ring core.

The strips are also drawn at a scale of 2:1 in order to make the similarities and differences between each sample more visible. If a tree ring is recorded as being 5 mm in width in the **sequence table**, learners should draw it at a scale of 2:1 (so 10 mm in width, across five of the background lines) on the recording strip.

Start at the left of the **tree ring recording strip** and draw **Ring 1** by counting the required number of divisions, then draw **Ring 2** by starting the next count of divisions from the line of **Ring 1**. Continue drawing from ring to ring in the same way until the strip is filled with the 30 measured ring widths from the **sequence table**. The completed strip should look just like the tree core illustrated on the **tree ring recording sheet**.

The 2:1 scale is used to make ring drawing on the **tree ring recording strip** easier and more accurate for learners using variable pencil thicknesses. Later on, the learners will be comparing several individual strips

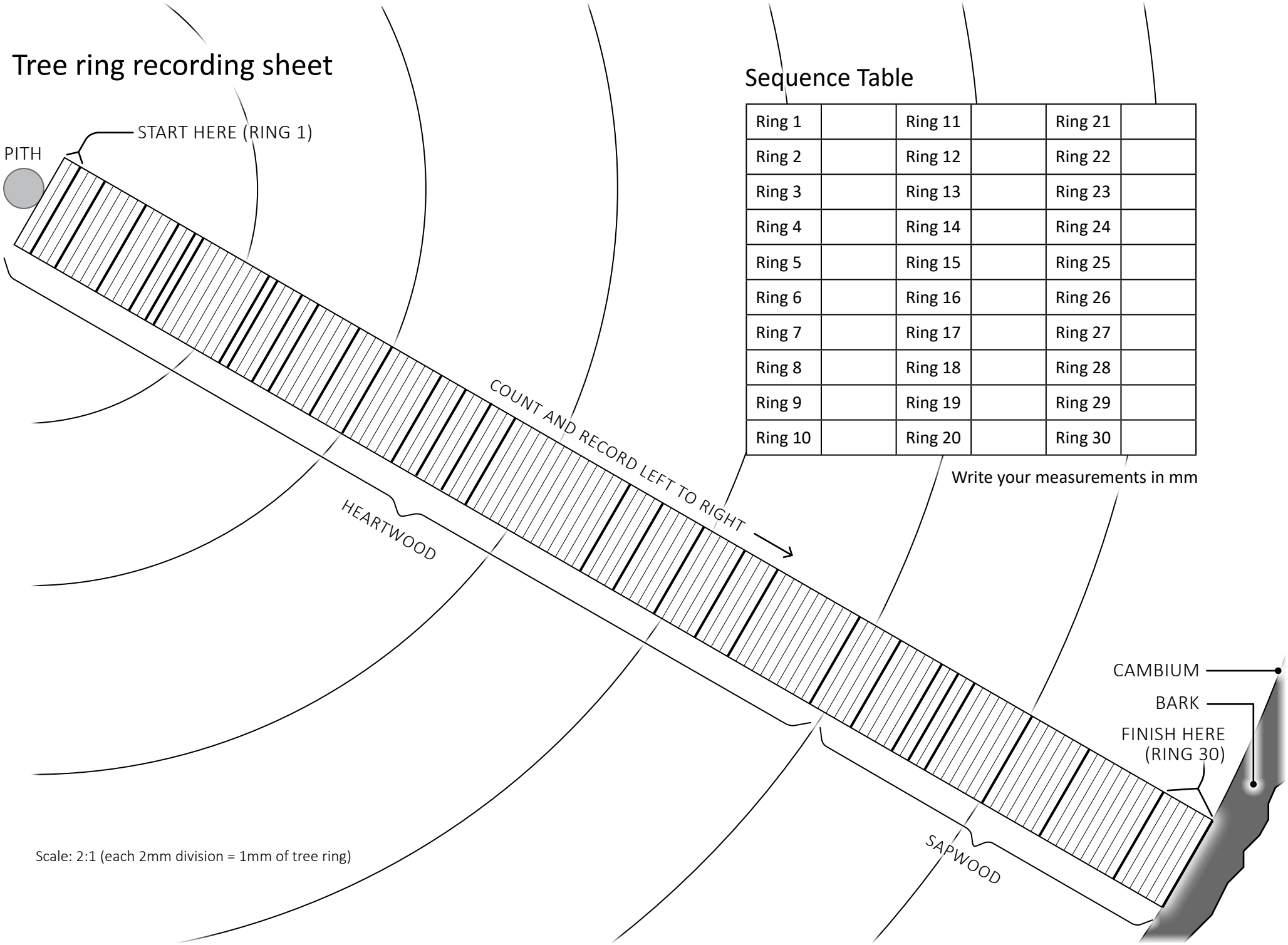
to find the overlaps they need to build their own *tree ring chronology*. Using this scale, the similarities and differences between each sample become more visible.

Set the sample coring date for **Ring 30** to the current year. By counting backwards from **Ring 30** (this year) to the *pith* (the centre, when the tree started to grow), learners can see that the tree core represents thirty years of tree growth to the current day. Use the tree core to relate directly to the learner's own life experiences and their community, such as the year they were born or when they started school, or when the school was built.

Questions for learners

- The last ring on the tree grew in this current year. On the tree ring core you have created write the year above **Ring 30**. Can you work out which ring was growing ten, fifteen and twenty years ago? What year is the first growth ring on the tree?
- Wide rings and narrow rings are grown by the tree in response to climate and other environmental conditions. Wide rings are grown by the tree when the environment and climate provide the best growing conditions. Narrow rings are grown in years when the tree finds growing conditions a struggle. Too much or too little water and sunlight can make growing conditions difficult for the trees. Looking at the rings and using what you have learned about growing conditions, what was special about **Ring 17** and which year was it grown in?
- What can the size of **Ring 6** tell you about the local growing conditions for the tree in that year?
- When this tree was growing were there more years of poor conditions or more years of good conditions for tree growth? What is your opinion and why?

Tree ring recording sheet



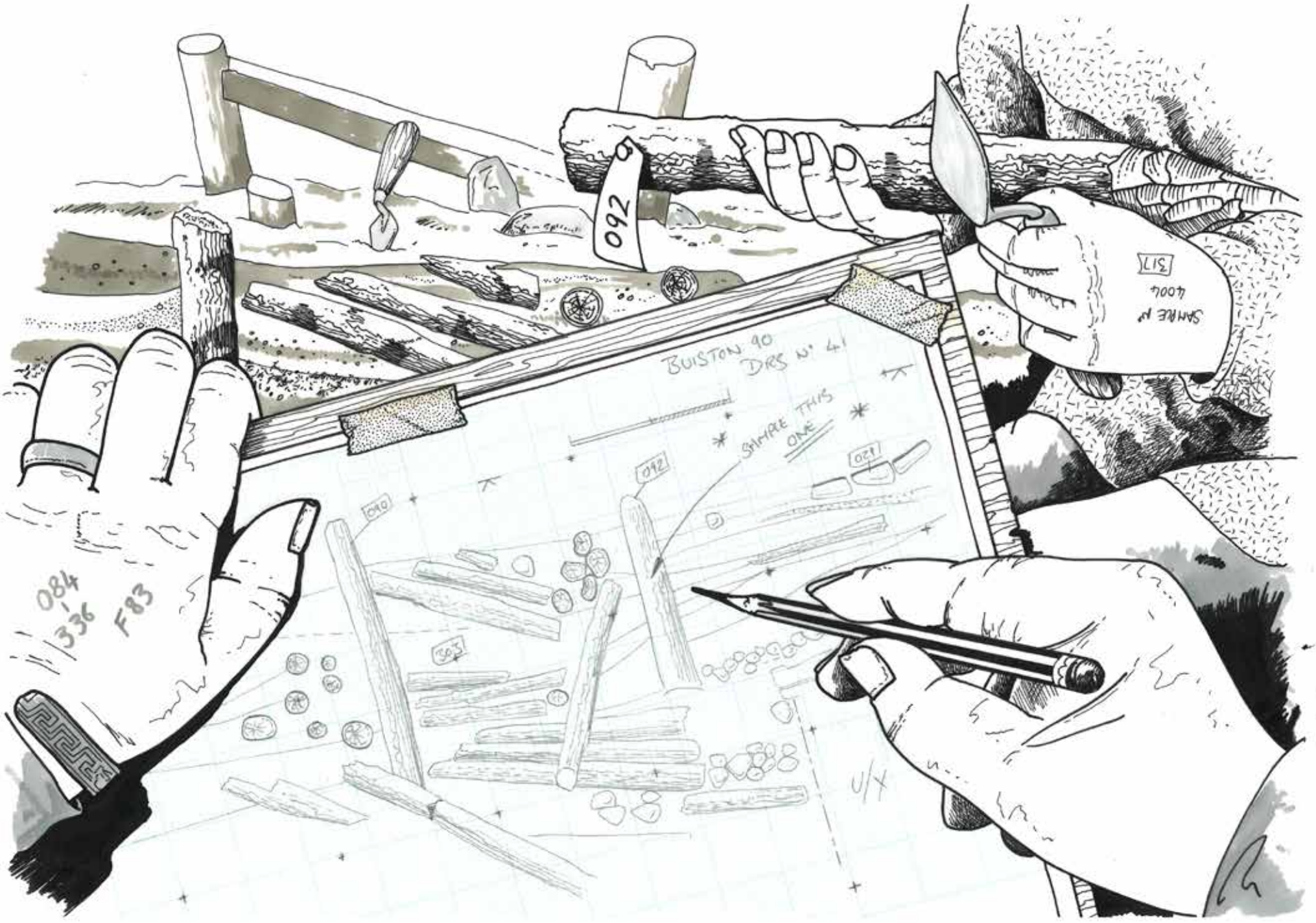
Sequence Table

Ring 1		Ring 11		Ring 21	
Ring 2		Ring 12		Ring 22	
Ring 3		Ring 13		Ring 23	
Ring 4		Ring 14		Ring 24	
Ring 5		Ring 15		Ring 25	
Ring 6		Ring 16		Ring 26	
Ring 7		Ring 17		Ring 27	
Ring 8		Ring 18		Ring 28	
Ring 9		Ring 19		Ring 29	
Ring 10		Ring 20		Ring 30	

Write your measurements in mm

Tree ring recording strips

Scale: 2:1 (each 2mm division = 1mm of tree ring)


092
SAMPLE N°
4006
317
BUISTON 90
DRS N° 41
SHARE THIS
ONE
092
090
120
363
084
336
F83
U/X

Excavating Buiston Crannog

Archaeological excavation has shown that Buiston crannog – an artificial island in an Ayrshire loch – had several phases of construction and occupation. The core of the structure was a mound of layers of turves and brushwood surrounded by a circle of oak stakes, all preserved in the waterlogged conditions. Radiocarbon dates showed that the initial mound was built in the first or second century AD. It contained no large timbers or tree trunks, so there are no dendrochronological dates for this period of construction. We know that people were living on the crannog mound at that time, but no direct structural evidence survived – and it was later abandoned, eventually becoming submerged by the waters of the loch.

But the crannog was to be reclaimed, and the next house that was built on the mound was to have its floor and hearth rebuilt three times (refreshing the living space in a way similar to us refitting the kitchen today). The crannog was then enlarged and a new roundhouse was built on the extension. Again, the floor and central hearth were rebuilt several times. Eventually, the extension to the crannog slumped and the house collapsed. The crannog was repaired by dumping more turves – and domestic and structural debris – into the hole, before a huge timber structure with a large palisade (or fence) and timber walkway was built over the whole island.

All of this information about the construction and use of the crannog comes from archaeological excavation – from working out the order in which layers of deposits were laid down. But excavation cannot tell us the dates at which these things happened. For this, archaeologists can use radiocarbon dating (which gives dates within a range, that can sometimes be as much as several hundred years) and dendrochronological dating (which can produce much more precise dates).

The major phases of occupation saw much oak timber being used in construction – meaning that a lot of dendrochronological dating was possible. When it was reclaimed from the loch, a large palisade was first built around the crannog in AD 550, followed by more substantial repair to the mound and the building of a house in AD 589. It took five years to fell the trees needed for this work. This house lasted for only five years, in which time it had its hearth replaced three times, at least once due to flooding.

In AD 594 the surface of the crannog was flattened and a new foundation layer and house were built. Over the next fifteen years, the floor and hearth in this house was replaced at least four times. A palisaded walkway had been built around the crannog in AD 608, only for the extension to slump and the walkway collapse. This may have happened in AD 613, because attempts were then made to repair the palisade. In AD 614 more trees began to be felled in order to prepare for the construction of a larger palisade and timber walkway, erected in AD 620. This seems to have strengthened the crannog for occupation well into the later seventh century AD.

Being able to obtain precise dates from dendrochronological dating has shown that the people living at Buiston were repairing and extending the crannog over many years – and were often preparing the timber that they would need several years in advance. While the archaeological excavation enables us to *understand* the basic phases of construction, the precise dendrochronological sequence allows a more human *appreciation* of the process of building and repair.

The Tree Ring Chronology

This activity creates a one hundred year *tree ring chronology* using five different tree cores and then uses this timeline to date an archaeological sample. The aim of this activity is to explain the process of combining sequences and cross-matching to build a simple *tree ring chronology*. This activity should be done in small groups, each creating their own timeline.

Five **tree ring recording** sheets have been provided, each representing one of the many different tree core samples that would be taken to create a *tree ring chronology* or regional *reference chronology*.

- Remember, every tree is unique. It's really important for the dendrochronologist to be able to sample as many trees as possible when they build a *tree ring chronology*. They can then start to smooth out any individual factors that may have affected an individual tree's ring growth (known as *noise*) and see the bigger picture for the whole wood or site (known as the *signal*).

The activity starts by recording the measurements from each ring in the sample using millimetres. The thirty tree ring measurements are written into the **sequence table** on the sheet. The **tree ring recording sheets** have been illustrated at a scale of 1:1.

Using the **tree ring recording strips**, ask your learners to carefully draw each ring line in the order recorded in their **sequence tables**.

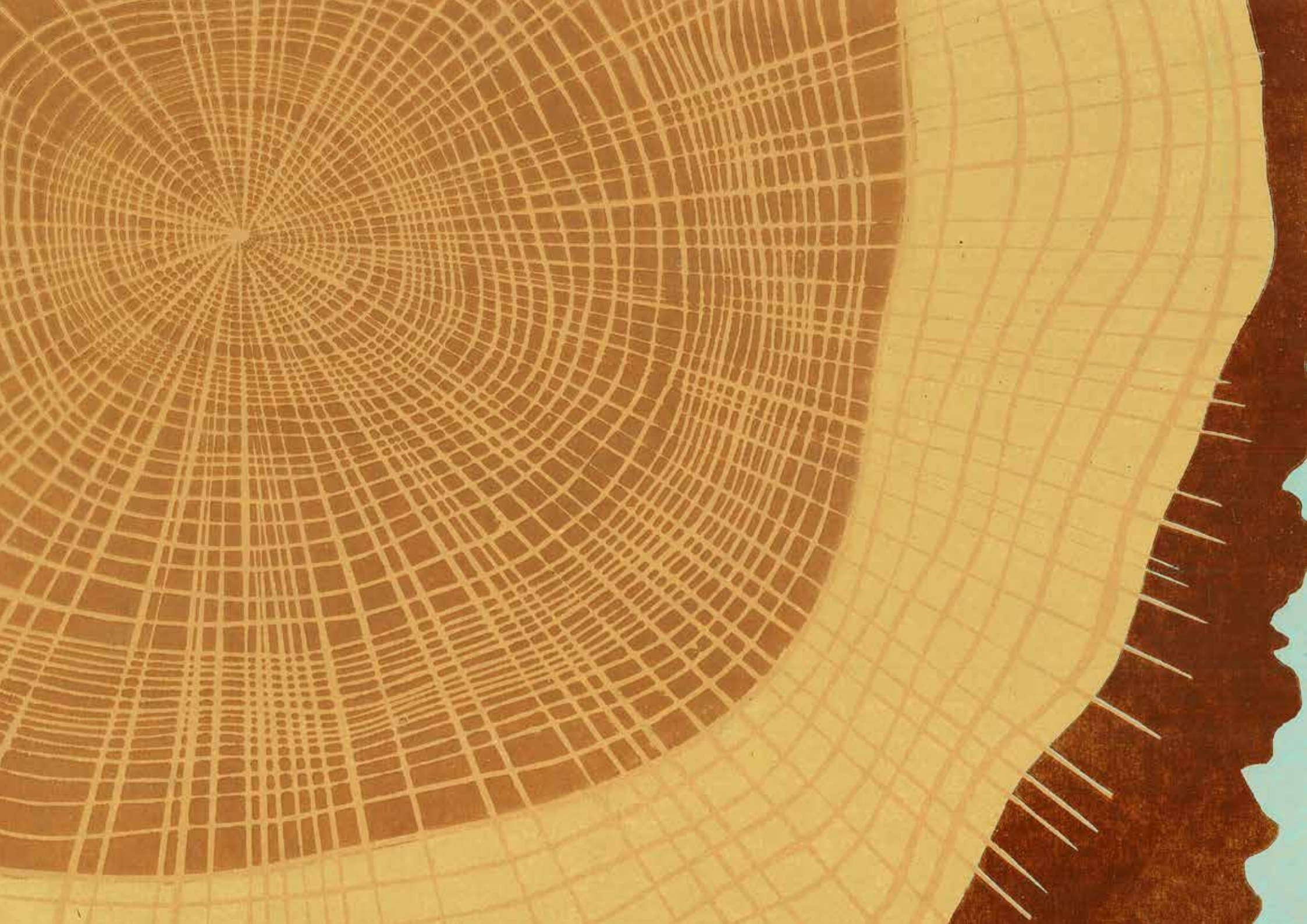
- Remember, the **tree ring recording sheets** have been illustrated at a scale of 1:1 but the **tree ring recording strips** are drawn at a scale of 2:1. This makes the similarities and differences between each sample more visible for matching the overlaps. If a tree ring is recorded as being 5 mm in width in the **sequence table**, learners should draw it at a scale of 2:1 (so 10 mm in width, across five of the background lines) on the recording strip.

The five tree cores overlap by varying amounts and can be assessed visually to find their order and overlap pattern.

- Remember, the patterns of wide and narrow growth rings should match exactly for the length of the overlapping sections. The overlap can be checked against the ring width measurements in each **sequence table**, as overlapping sections should also have identical ring measurements recorded in millimetres. Completed versions of the sequence tables can be found on page 31.

Once the points of overlap have been discovered the five **tree ring recording strips** can be placed over each other and joined together to build up into one single *tree ring chronology*.

- Use the **Timelines with Tapes** activity in *Outdoor Archaeological Learning* to help demonstrate the concept of chronology and time. The timeline can be used to explain that the *tree ring chronology* the learners have produced is only one part of a longer timeline that stretches back many thousands of years.



Dating an archaeological sample

The *tree ring chronology* is one hundred years in length. Imagine it represents the 9th century AD (801 – 900 AD), when Scotland first saw Viking raids. The *tree ring chronology* can be given dates using the convention that **Ring 1** is 801 AD and **Ring 100** is 900 AD.

The **archaeological sample recording sheet** represents the *tree ring sequence* of a timber from an imagined Viking ship, preserved in the silt and cold waters of a Scottish sea loch. Create a **tree ring recording strip** for this and place it against your *tree ring chronology* to find where the pattern of rings matches.

The date of the most recent ring (or last ring known) in the archaeological sample is referred to as the *terminus post quem*, a Latin phrase meaning the 'limit after which' and which is used in dendrochronology to say the 'date after which' a tree was felled. This is the last year we can say for sure that the tree was growing. The ship timber from which the sample was taken must have been made either during that year or after it. The 'or after' is really important, as the dated tree core sample cannot tell us how long after the tree was cut down the timber from it was used – and sometimes timbers were reused from elsewhere!

Terminus post quem is also used to describe the secure date that the archaeologists are certain of, after which the action or event they are interested in occurs. It is used in dendrochronology when a precise date or *felling date range* cannot be given – usually when there is no *sapwood* present. If partial *sapwood* is present on an oak timber then a *felling date range* can be given. This will be explored further in the next activity, where the use of the term *terminus post quem* for felling is demonstrated further.

- You can use a handful of coins to demonstrate the *terminus post quem* principle. The most recently manufactured coin provides the *terminus post quem* for the whole collection but is likely several years before today's date – the date at which the various coins were collected together in your hand. If archaeologists found a buried hoard of coins, the most recent coin provides the *terminus post quem* after which the hoard must have been buried. But without further dating evidence, the archaeologists still don't know exactly when the hoard was buried.

Questions for learners

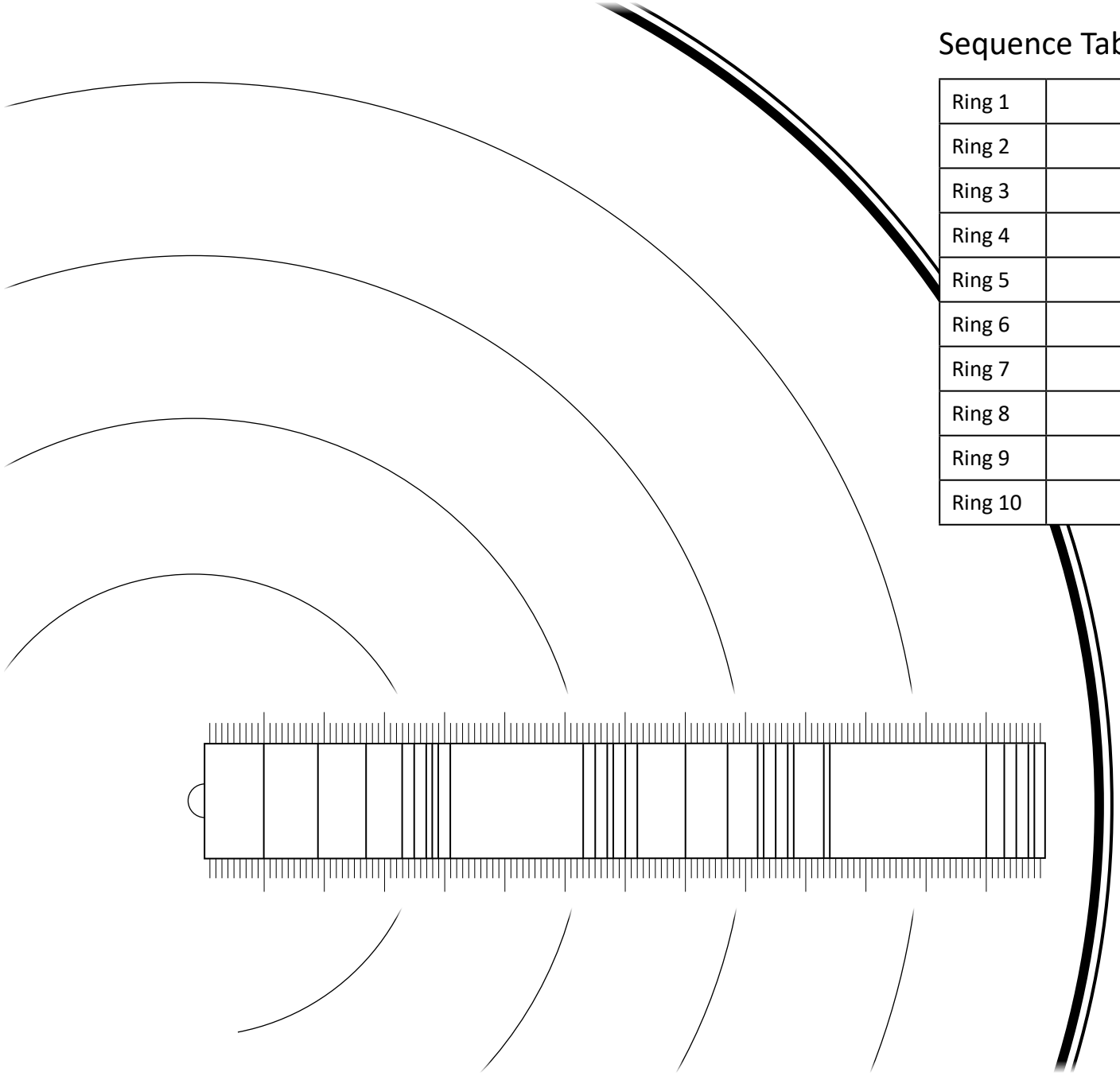
- Count the rings to find out how many years are in your *tree ring chronology*. Do you know what a time period lasting that length of years is called? (A century)
- Several periods of poor conditions for tree ring growth are present in the *tree ring chronology*. Can you find an example that lasted over seven years and work out the date in years that this happened? (AD 815 – 822 or AD 876 – 885)

Remember, oak has a predictable number of *sapwood* rings; there are usually a minimum of 10 and a maximum of 55 *sapwood* rings present on British oak. This is known as the *sapwood range*. When no *sapwood* is present in the sample, in order to discover the *terminus post quem* you must add 10 years onto the last known date on the tree ring sequence to reflect the minimum of 10 sapwood rings that would have been present when the tree was felled.

Ask your learners to date the archaeological sample using their *tree ring chronology* to find the *terminus post quem* for the felling of the timber used in the construction of the ship. Identifying the last ring date gives us the last known date that the tree was growing that produced the timber. The date is *terminus post quem* because the timber did not include *sapwood* or a *bark* edge so we do not know how long afterwards the tree was felled.

- What is the date of the last ring preserved on this timber? (AD 860)
- What is the *terminus post quem* – the date after which the timber was felled? (AD 870)
- Why is this a *terminus post quem*? (With no *sapwood* or *bark* preserved in the timber, dendrochronologists cannot precisely identify the *felling year* or estimate the *felling date range*)

Tree ring recording sheet (Sample 1)

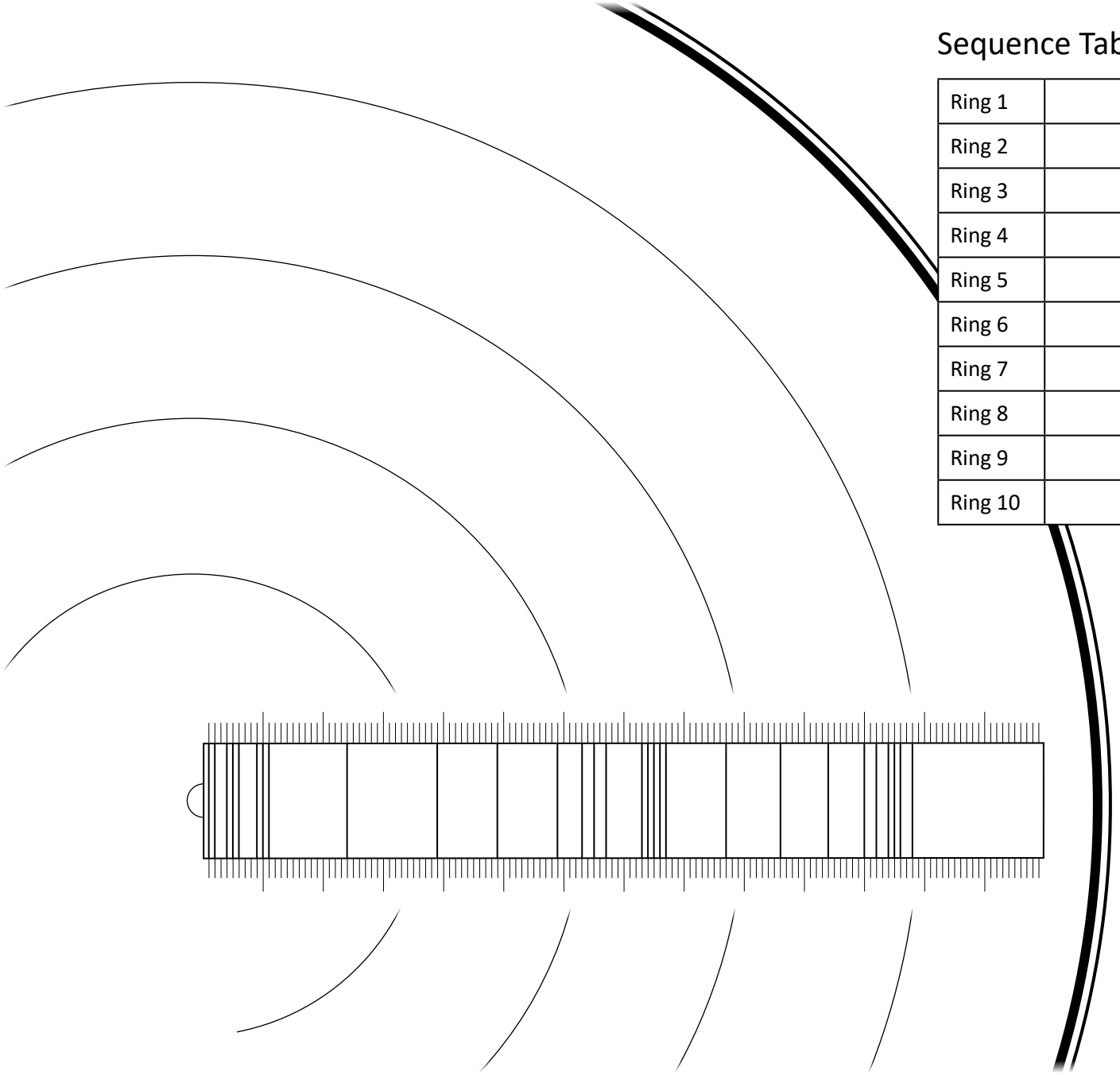


Sequence Table

Ring 1		Ring 11		Ring 21	
Ring 2		Ring 12		Ring 22	
Ring 3		Ring 13		Ring 23	
Ring 4		Ring 14		Ring 24	
Ring 5		Ring 15		Ring 25	
Ring 6		Ring 16		Ring 26	
Ring 7		Ring 17		Ring 27	
Ring 8		Ring 18		Ring 28	
Ring 9		Ring 19		Ring 29	
Ring 10		Ring 20		Ring 30	

Write your measurements in mm

Tree ring recording sheet (Sample 2)

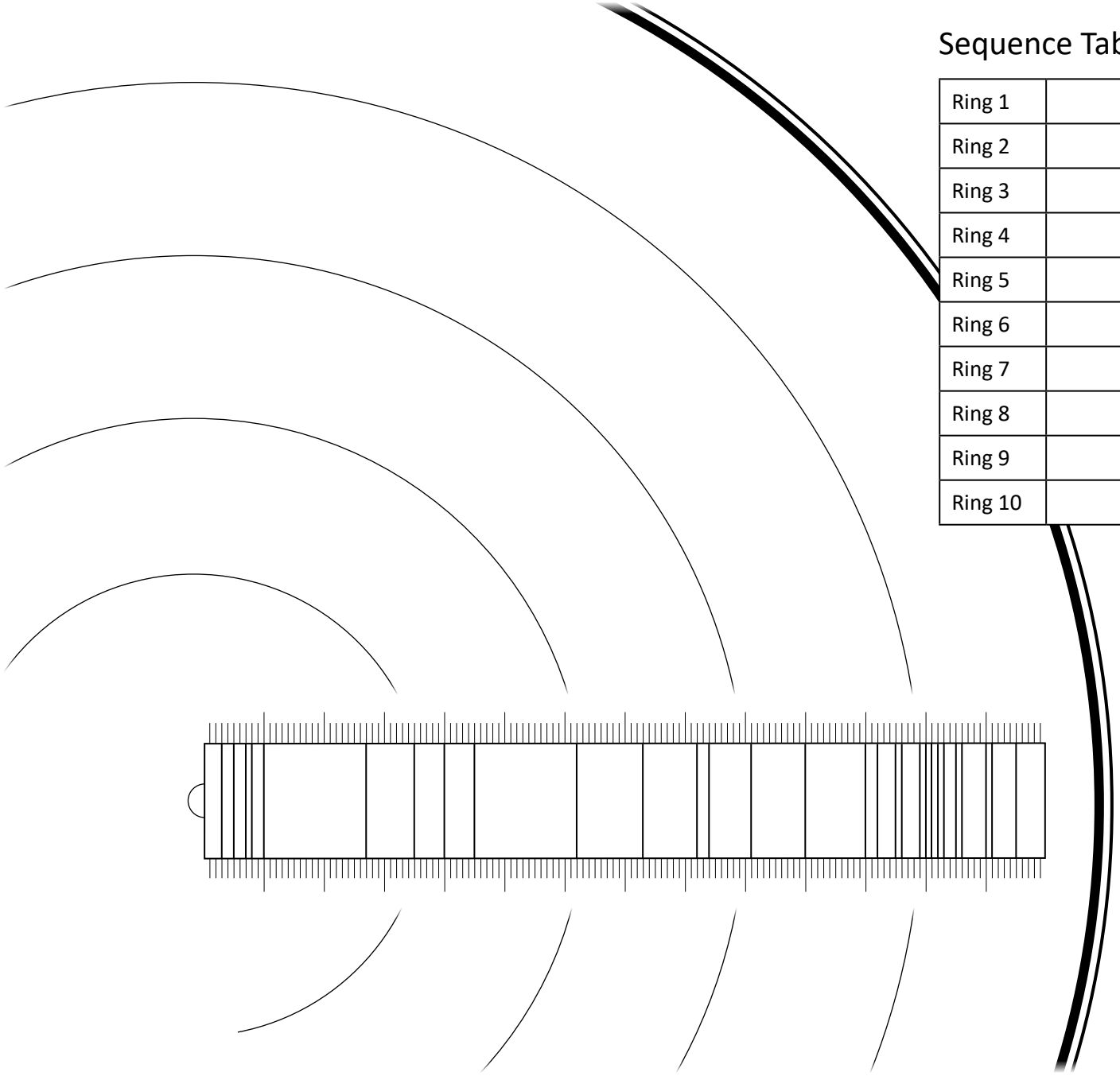


Sequence Table

Ring 1		Ring 11		Ring 21	
Ring 2		Ring 12		Ring 22	
Ring 3		Ring 13		Ring 23	
Ring 4		Ring 14		Ring 24	
Ring 5		Ring 15		Ring 25	
Ring 6		Ring 16		Ring 26	
Ring 7		Ring 17		Ring 27	
Ring 8		Ring 18		Ring 28	
Ring 9		Ring 19		Ring 29	
Ring 10		Ring 20		Ring 30	

Write your measurements in mm

Tree ring recording sheet (Sample 3)

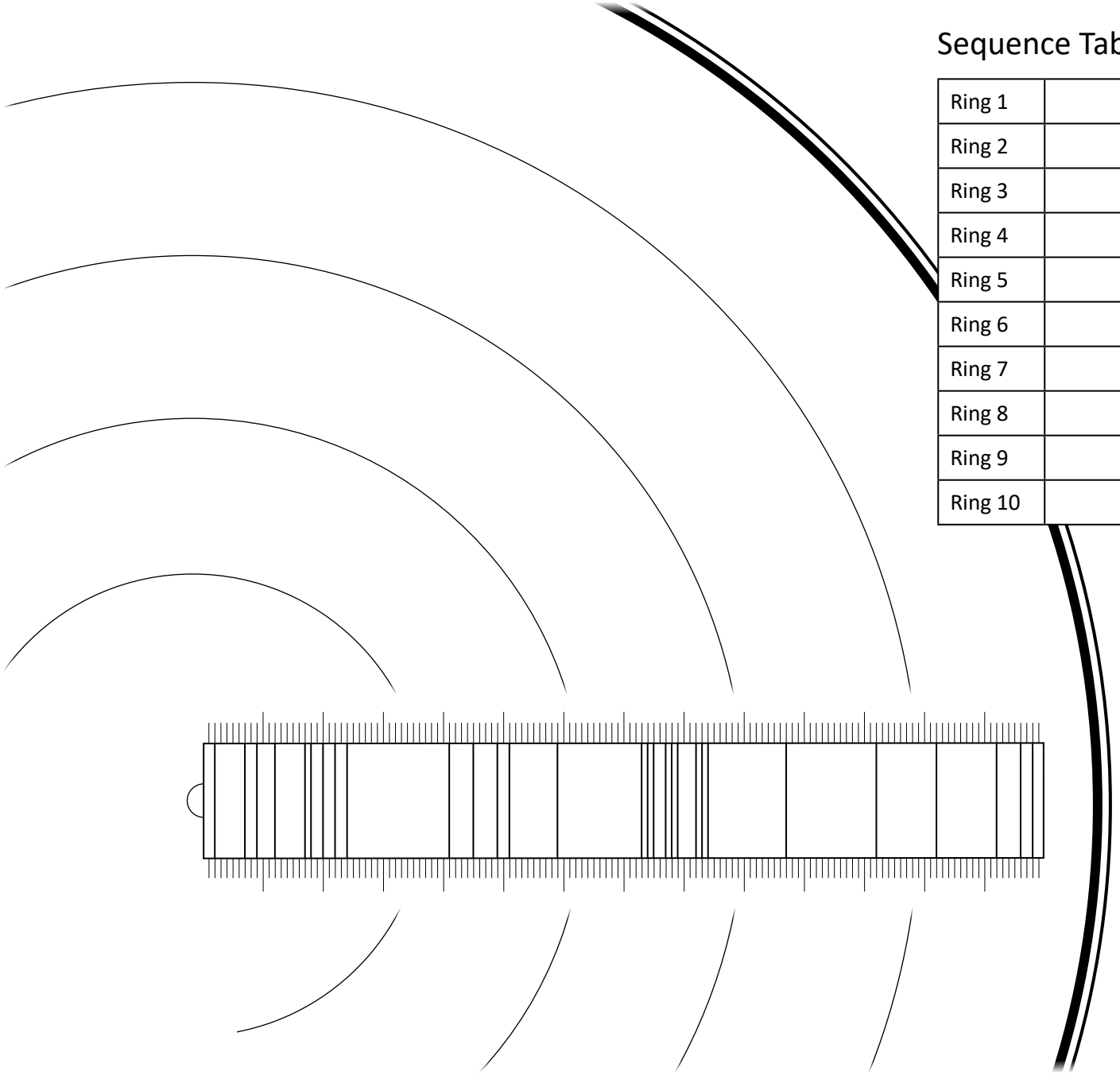


Sequence Table

Ring 1		Ring 11		Ring 21	
Ring 2		Ring 12		Ring 22	
Ring 3		Ring 13		Ring 23	
Ring 4		Ring 14		Ring 24	
Ring 5		Ring 15		Ring 25	
Ring 6		Ring 16		Ring 26	
Ring 7		Ring 17		Ring 27	
Ring 8		Ring 18		Ring 28	
Ring 9		Ring 19		Ring 29	
Ring 10		Ring 20		Ring 30	

Write your measurements in mm

Tree ring recording sheet (Sample 4)

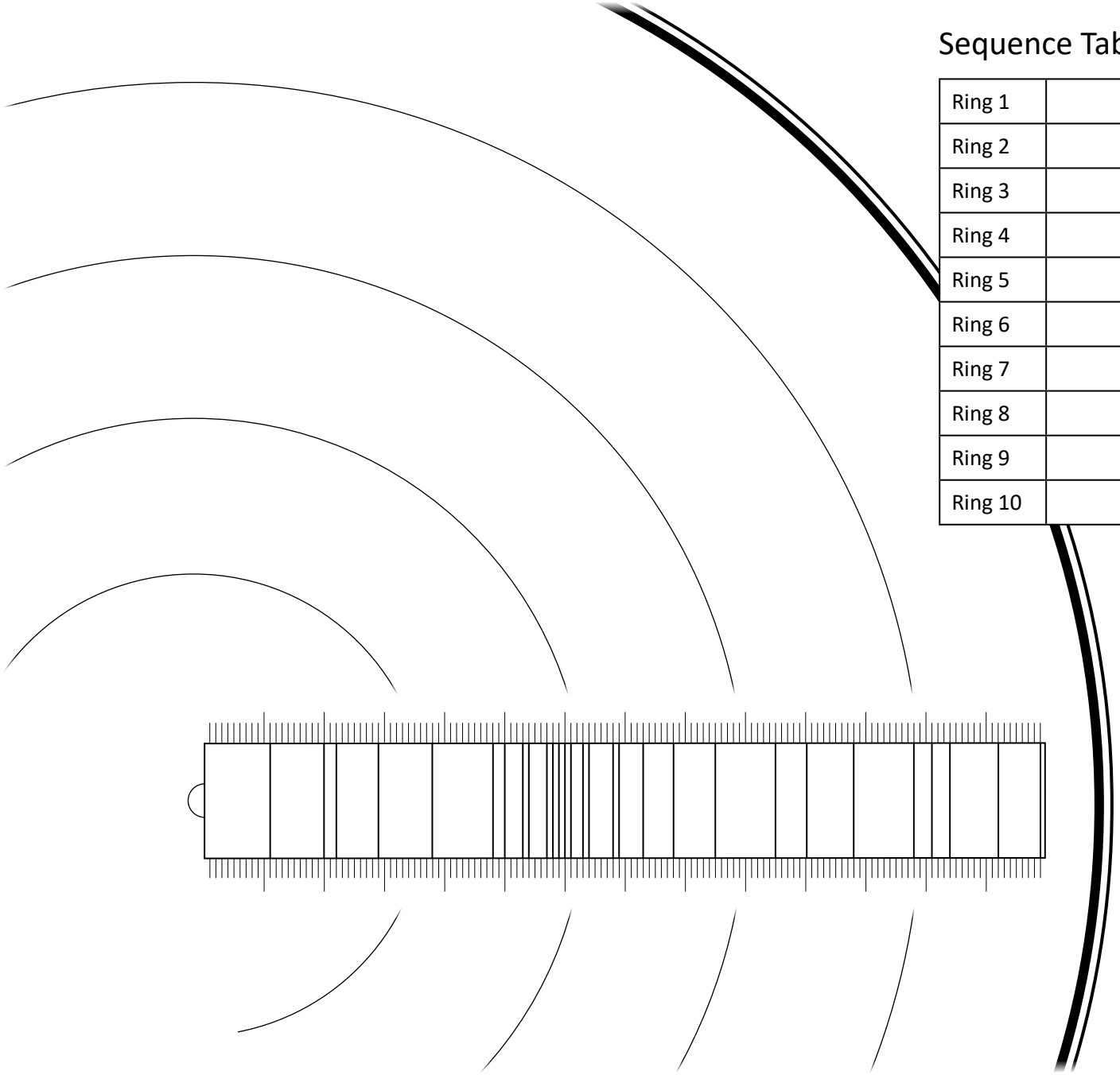


Sequence Table

Ring 1		Ring 11		Ring 21	
Ring 2		Ring 12		Ring 22	
Ring 3		Ring 13		Ring 23	
Ring 4		Ring 14		Ring 24	
Ring 5		Ring 15		Ring 25	
Ring 6		Ring 16		Ring 26	
Ring 7		Ring 17		Ring 27	
Ring 8		Ring 18		Ring 28	
Ring 9		Ring 19		Ring 29	
Ring 10		Ring 20		Ring 30	

Write your measurements in mm

Tree ring recording sheet (Sample 5)

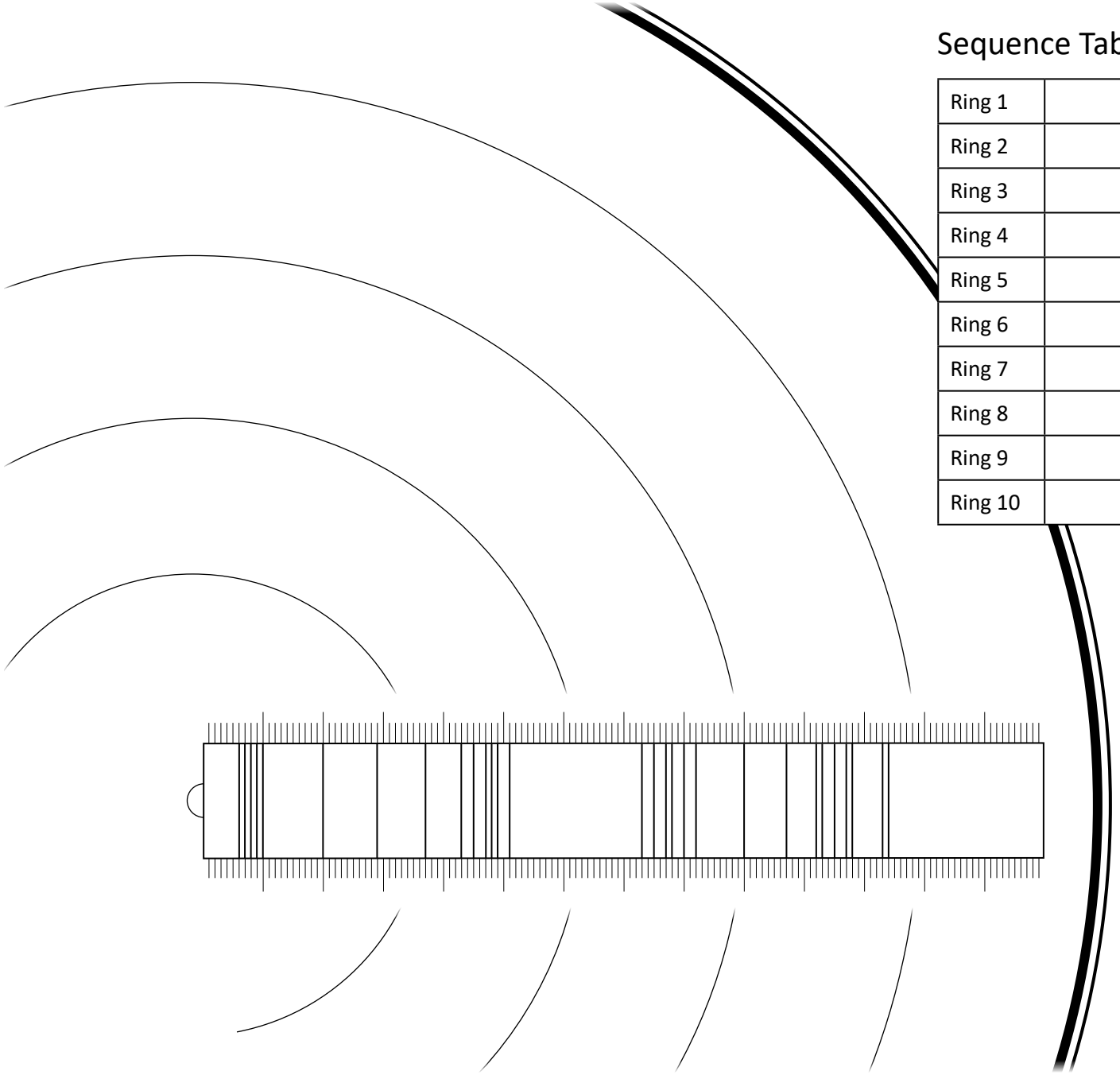


Sequence Table

Ring 1		Ring 11		Ring 21	
Ring 2		Ring 12		Ring 22	
Ring 3		Ring 13		Ring 23	
Ring 4		Ring 14		Ring 24	
Ring 5		Ring 15		Ring 25	
Ring 6		Ring 16		Ring 26	
Ring 7		Ring 17		Ring 27	
Ring 8		Ring 18		Ring 28	
Ring 9		Ring 19		Ring 29	
Ring 10		Ring 20		Ring 30	

Write your measurements in mm

Tree ring recording sheet (Archaeological Sample)



Sequence Table

Ring 1		Ring 11		Ring 21	
Ring 2		Ring 12		Ring 22	
Ring 3		Ring 13		Ring 23	
Ring 4		Ring 14		Ring 24	
Ring 5		Ring 15		Ring 25	
Ring 6		Ring 16		Ring 26	
Ring 7		Ring 17		Ring 27	
Ring 8		Ring 18		Ring 28	
Ring 9		Ring 19		Ring 29	
Ring 10		Ring 20		Ring 30	

Write your measurements in mm

Sequence Table (Sample 1)

Ring 36	10	Ring 46	2	Ring 56	2
Ring 37	9	Ring 47	2	Ring 57	1
Ring 38	8	Ring 48	1	Ring 58	5
Ring 39	6	Ring 49	2	Ring 59	1
Ring 40	2	Ring 50	2	Ring 60	26
Ring 41	2	Ring 51	8	Ring 61	3
Ring 42	1	Ring 52	7	Ring 62	2
Ring 43	1	Ring 53	5	Ring 63	2
Ring 44	2	Ring 54	1	Ring 64	1
Ring 45	22	Ring 55	2	Ring 65	2

Measurements in mm

Sequence Table (Sample 2)

Ring 16	1	Ring 26	10	Ring 36	10
Ring 17	1	Ring 27	10	Ring 37	9
Ring 18	2	Ring 28	4	Ring 38	8
Ring 19	1	Ring 29	2	Ring 39	6
Ring 20	1	Ring 30	2	Ring 40	2
Ring 21	3	Ring 31	6	Ring 41	2
Ring 22	1	Ring 32	1	Ring 42	1
Ring 23	1	Ring 33	1	Ring 43	1
Ring 24	13	Ring 34	1	Ring 44	2
Ring 25	15	Ring 35	1	Ring 45	22

Measurements in mm

Sequence Table (Sample 3)

Ring 61	3	Ring 71	11	Ring 81	1
Ring 62	2	Ring 72	9	Ring 82	1
Ring 63	2	Ring 73	2	Ring 83	1
Ring 64	1	Ring 74	7	Ring 84	1
Ring 65	2	Ring 75	9	Ring 85	2
Ring 66	17	Ring 76	10	Ring 86	1
Ring 67	8	Ring 77	2	Ring 87	4
Ring 68	5	Ring 78	3	Ring 88	1
Ring 69	5	Ring 79	1	Ring 89	4
Ring 70	17	Ring 80	3	Ring 90	5

Measurements in mm

Sequence Table (Sample 4)

Ring 1	2	Ring 11	4	Ring 21	3
Ring 2	5	Ring 12	4	Ring 22	1
Ring 3	2	Ring 13	2	Ring 23	1
Ring 4	3	Ring 14	8	Ring 24	13
Ring 5	5	Ring 15	14	Ring 25	15
Ring 6	1	Ring 16	1	Ring 26	10
Ring 7	2	Ring 17	1	Ring 27	10
Ring 8	2	Ring 18	2	Ring 28	4
Ring 9	2	Ring 19	1	Ring 29	2
Ring 10	17	Ring 20	1	Ring 30	2

Measurements in mm

Sequence Table (Sample 5)

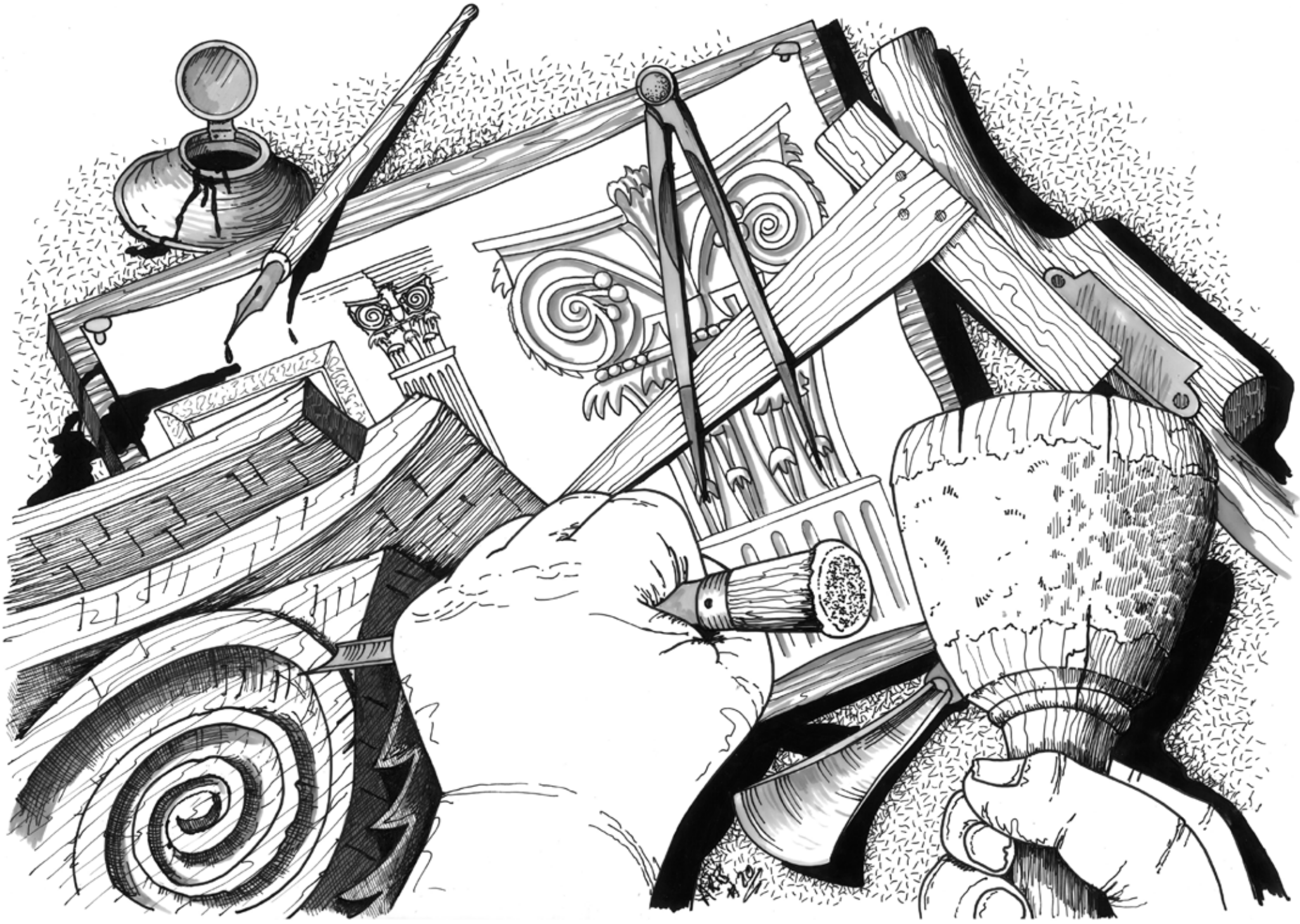
Ring 71	11	Ring 81	1	Ring 91	7
Ring 72	9	Ring 82	1	Ring 92	10
Ring 73	2	Ring 83	1	Ring 93	5
Ring 74	7	Ring 84	1	Ring 94	8
Ring 75	9	Ring 85	2	Ring 95	10
Ring 76	10	Ring 86	1	Ring 96	3
Ring 77	2	Ring 87	4	Ring 97	3
Ring 78	3	Ring 88	1	Ring 98	8
Ring 79	1	Ring 89	4	Ring 99	7
Ring 80	3	Ring 90	5	Ring 100	1

Measurements in mm

Sequence Table (Archaeological Sample)

Ring 31	6	Ring 41	2	Ring 51	8
Ring 32	1	Ring 42	1	Ring 52	7
Ring 33	1	Ring 43	1	Ring 53	5
Ring 34	1	Ring 44	2	Ring 54	1
Ring 35	1	Ring 45	22	Ring 55	2
Ring 36	10	Ring 46	2	Ring 56	2
Ring 37	9	Ring 47	2	Ring 57	1
Ring 38	8	Ring 48	1	Ring 58	5
Ring 39	6	Ring 49	2	Ring 59	1
Ring 40	2	Ring 50	2	Ring 60	26

Measurements in mm



Analysing the oak capitals from Hamilton Palace

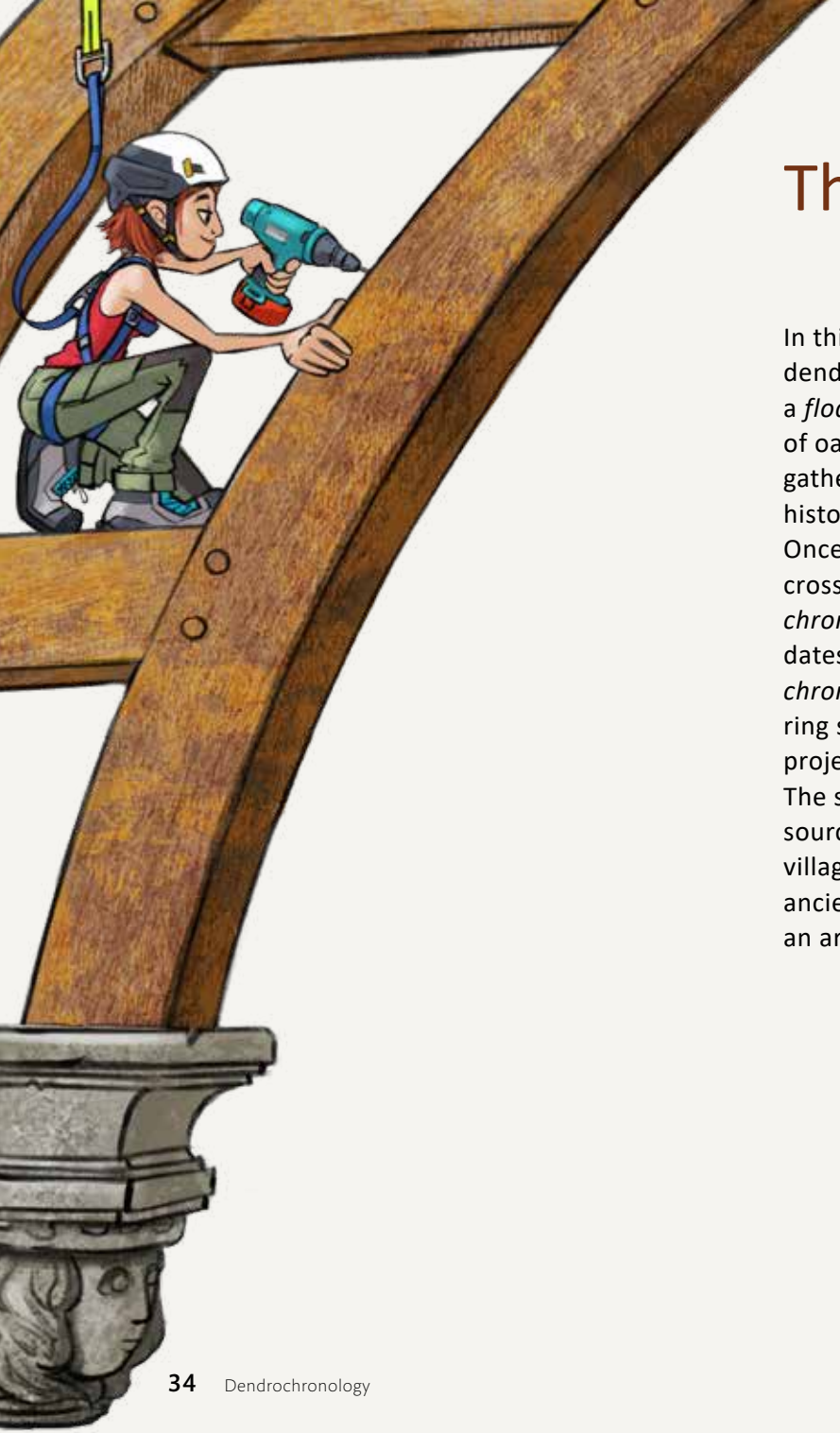
Hamilton Palace was the seat of a Scottish noble family. Already very wealthy, in the 18th and 19th centuries, during the Industrial Revolution, the Hamiltons made a fortune from their ownership of the Lanarkshire coal fields. They rebuilt and remodelled Hamilton Palace throughout the 17th to 19th centuries. The renovations were extravagant and elaborate, both inside and out. The history of the grand and intricate wooden panelled interior of the Palace is complex, but historical sources suggest it was created following plans developed by architect William Murray around 1692. The interior of the palace included intricately carved wooden capitals, which echoed the grand Corinthian pillars on its exterior.

The elaborate wooden interior of the Palace required a large amount of oak timber, for construction and decoration. Tree ring analysis has shown that most of the timber used for construction in Scotland at the time was imported from abroad. However, nearby woodland, then within the Hamilton's estate, contains some very ancient oak trees today. These trees, known as the Cadzow oaks, have been analysed by dendrochronologists. They are a key element in the long oak tree ring *reference chronology* for south-west Scotland, which spans from AD 1444 to 1984. These trees would have already been mature, and suitable for building with, at the end of the 17th century, so it seems likely that this local woodland would also have provided some material for the interior of the palace.

The science of dendrochronology can give us information about *provenance* – about where the tree that the timber came from was grown – as well as giving a date for when the tree stopped growing. A sample from one of the capitals was analysed to see if it had been made of this locally grown oak source, and to test the historic records about the date of the construction of the grand interior of the palace.

It was shown that timber that made up a part of the capital came from a tree that stopped growing in AD 1682-3. It is likely that the timber used for creating this intricate capital was seasoned for several years before being used, which fits in with the historical record of AD 1692 for the refurbishing of the palace interior. The sample was found to be a close match with the Cadzow oaks, suggesting that it did come from locally sourced wood.

Hamilton Palace was eventually demolished in 1927, ironically due to subsidence caused by the coal mines which had financed its multiple redesigns and opulent appearance.



The Reference Chronology

In this activity the learners are working as dendrochronologists. First they must build a *floating chronology* using a huge set of oak tree *ring sequences* that has been gathered from ancient woodlands and historic buildings from across their region. Once their *floating chronology* has been cross referenced to a known *reference chronology* and fixed in time to calendar dates, they must use their own *reference chronology* to investigate a series of tree ring samples from a landscape heritage project, centred on a small historic town. The samples all come from a variety of sources in the town and surrounding villages, including several historic buildings, ancient woodlands, museum artefacts and an archaeological excavation.

The sequence graph recording sheet

The aim of this activity is to explain the process of building a long *floating chronology* using the tree ring sequence graph method. The learners must then work together to convert this into a dated regional *reference chronology* spanning one thousand years. The **sequence graphs** of five archaeological samples taken from medieval and post medieval buildings can then be placed against the *reference chronology* and precisely dated or their *terminus post quem* for felling assessed.

The tree ring samples are presented as numerical measurements, and the learners must plot them using the **sequence graph recording sheets**. The chronology to be built uses thirty overlapping **sequence graphs**, each representing 50 years of ring growth. This activity should be done individually and then as a class.

When working with smaller groups, there are both blank and prepared **sequence graph recording sheets** provided which can be used together to complete the activity and build the regional reference chronology. Once created, the chronology can be displayed as a large wall poster.

Building the floating chronology

A huge set of *tree ring sequences* has been gathered from ancient woodlands and historic buildings from across the region. These samples from have been collected, measured and averaged to reduce noise from individual samples. The resulting smoothed ring measurements have been placed into a **sequence table**. There are thirty different **sequence graph recording sheets** to allow each individual to produce a **sequence graph** based on their individual **sequence table**.

- **Sequence graphs** are another way that tree ring growth patterns can be represented and visualised in dendrochronology.

Each **sequence graph recording sheet** is named with a letter and number combination (D1, N3, E2 etc). These combinations form a code which when placed in the correct order will spell the phrase DENDROCHRONOLOGY/ TREE/RING/DATING. This can be used as a secret key to the sample order when the learners are building the regional *floating chronology* by eye.

Each **sequence graph** overlaps with another two patterns in the activity: the preceding and following **sequence graphs** in the series. The overlap is produced from the first and last sixteen ring data measurement points in each **sequence table** (excepting D1 and G3, which form the beginning and end of the sequence respectively and overlap at one end only).

Once each **sequence graph** is plotted, they can be compared and combined together to produce one long regional *floating chronology*. This may be difficult at first, but once a few overlaps have been identified and agreed, it should become easier and easier to join the groups together.

- You could carefully cut and tape your *reference chronology* together into one long timeline, or stagger it in a zig-zagging 'one up, one down' pattern. Glue your timeline onto a roll of paper so that you can mark on calendar dates later.

In this activity the overlapping points of the **sequence graphs** reproduce the comparisons between *tree ring chronologies*, and each graph overlaps with the next in the series. There is a large enough overlap that it is possible to visually assess this overlap and build the timeline. When laid in an overlapping line, the **sequence graphs** create one long continuous timeline of tree rings representing 1,036 years.

- Remember, dendrochronologists will analyse lots of different tree ring samples, looking for patterns of overlap in the measurements to produce a *tree ring chronology*. When compared with other *tree ring chronologies* from a similar *provenance* (or place) they can produce a larger regional *floating chronology*.

  To become a *reference chronology*, the sequence must connect to the present day with samples taken from living trees in the historic woodlands to provide the anchor in time.

Building the reference chronology

The new *floating chronology* has now been linked to the regional *reference chronology* with known dates fixed in time by linking to living tree records. This cross-matching process has given us a secure absolute (or calendar) date of AD 1858 for the most recent ring of our chronology – and our *floating chronology* has become a new *reference chronology*. By following the annual growth rings back in time, every ring in the project's chronology can be matched with a calendar date.

Key calendar dates can be written alongside points on the newly created *reference chronology*. Once the whole sequence has been dated it can be seen that the record of tree ring growth stretches from AD 823 to AD 1858 – over a thousand years and spanning the 9th to the 19th century.

- If you have glued your timeline onto a roll of paper, you can now annotate key dates alongside, and mark out the centuries.

Using the reference chronology

Dendrochronologists use *reference chronologies* to date tree ring samples obtained from archaeological artefacts and timbers from historic buildings. Using the most recent ring they can ascribe a date after which the artefact was created or discover a *felling year* or *felling date range* for the timber used in construction of the building they are investigating.

There is usually a mix of sample types in any dendrochronological project, from tree cores taken from living trees, discs cut from fallen trees, timber cores taken from historic buildings and slices cut from archaeological timbers – even impressions taken from *in situ* building timbers and photographs of *tree ring sequences*.

Five **archaeological sample recording sheets** have been prepared for timber samples from archaeological sites and historic buildings. Using the newly dated *reference chronology*, the learners can now work out either the precise *felling year*, an estimated *felling date range* or a *terminus post quem* for each sample by matching the **sequence graph** patterns.

- It is possible to precisely date the last tree ring as the *felling year* if a sample still has some *bark* attached.
- It is possible to estimate and date the *felling date range* of a sample if some *sapwood* remains.
- If no *bark* or *sapwood* is visible at all, it is only possible to identify a *terminus post quem* – the date after which the timber was felled.

Questions for learners

Sample 1

Sample 1 is an archaeological disc sample that comes from the timber piles from the foundations of an old bridge that once crossed the river, found preserved in the silt of its bank. The oak timbers are waterlogged and this has helped ensure their preservation. The *anaerobic* conditions (*anaerobic* means 'without oxygen') have stopped bacteria from attacking the wood and causing decay. The sample also still has some *bark* attached, so the last tree ring indicates the precise year the tree was cut down (known as the *felling year*). Once you have matched the sample's **sequence graph** pattern to your *reference chronology* you can work out how old your sample is and use the dates discovered to learn more about the time period it comes from.

- What is the date of the earliest ring on your sample? (AD 1033)
- What is the date of the *felling year* of this timber? (AD 1067)
- Why is this the *felling year*? (The bark indicates that the last ring was the last growing year)

Sample 2

Sample 2 is a core that comes from oak timber rafters in the church roof. Once you have matched the sample's **sequence graph** pattern to your *reference chronology* you can work out how old your sample is and use the dates discovered to learn more about the time period it comes from.

Ask your learners to date the archaeological sample using their *tree ring chronology* to find the *terminus post quem* for the felling of the timber used in the construction of the church. Identifying the last ring date gives us the last known date that the tree was growing that produced the timber. The date is *terminus post quem* because the timber did not include *sapwood* or a *bark* edge so we do not know how long afterwards the tree was felled.

However, oak has a predictable number of *sapwood* rings – and there are usually a minimum of 10 and a maximum of 55 *sapwood* rings present on British oak. This is known as the *sapwood range*. To discover the *terminus post quem* – the date after which the timber was felled – you must add 10 years onto the last known date on the tree ring sequence to reflect the minimum of 10 sapwood rings that would have been present.

- What is the date of the earliest ring on your sample? (AD 1280)
- What is the date of the last ring preserved on this timber? (AD 1314)

- What is the *terminus post quem* – the date after which the timber was felled? (AD 1324)
- What is a timber rafter? (Rafters are made from long timbers and are used in buildings to form part of the internal frame of the roof. Structural timbers like rafters are also known as beams)

Sample 3

Sample 3 is a slice that comes from an oak floor timber in one of the historic townhouses in the oldest part of the town. The timber was in the floor of an upper bedroom. It was slice sampled when being removed and replaced due to rot. It is known from documentary sources that a house was built at or near the townhouse by Nathaniel Duncanson, a wealthy merchant on the occasion of his marriage in AD 1636. Once you have matched the sample's *tree ring sequence* to your *reference chronology* you can work out how old your sample is and use the dates discovered to learn more about the time period it comes from.

Ask your learners to date the archaeological sample using their *tree ring chronology* to find the *terminus post quem* for the felling of the timber used in the floor of the townhouse. Identifying the last ring date gives us the last known date that the tree was growing that produced the timber. The date is *terminus post quem* because the timber did not include *sapwood* or a *bark* edge so we do not know how long afterwards the tree was felled.

However, oak has a predictable number of *sapwood* rings – and there are usually a minimum of 10 and a maximum of 55 *sapwood* rings present on British oak. This is known as the *sapwood range*. To discover the *terminus post quem* – the date after which the timber was felled – you must add 10 years onto the last known date on the *tree ring sequence* to reflect the minimum of 10 *sapwood* rings that would have been present.

- What is the date of the earliest ring on your sample? (AD 1578)
- What is the date of the last ring preserved on this timber? (AD 1612)
- What is the *terminus post quem* – the date after which the timber was felled? (AD 1622)
- What is timber flooring? (Flooring is made from long timbers sliced into flat planks or boards. They are used in buildings to form the walking surface in a room and can also be known as floorboards. Can you see any wooden floorboards in the building you are in?)
- There is a difference between the dates of the archaeological sample and the documentary source. Can you think of any reasons why this might be? (There are several possible explanations for the different dates: the timbers could have been cut down to be shaped into planks and may have lost some of the outer rings that would give them a later date; the floor could have been reused or recycled from an earlier house; the date of Nathaniel's marriage on the primary source document could have been recorded wrongly or the document was not referring to the house we are investigating but another property he built later. There are many other reasons that might be just as valid. This demonstrates why a more rounded picture is achieved using multiple sources of investigation and can help when reconstructing past events)

Sample 4

Sample 4 is a core that came from one of the exposed oak timber joists in the ceiling above the bar in a historic tavern. Once you have matched the sample's **sequence graph** pattern to your *reference chronology* you can work out how old your sample is and use the dates discovered to learn more about the time period it comes from.

Ask your learners to date the archaeological sample using their *tree ring chronology* to find the *terminus post quem* for the felling of the timber used in the tavern's ceiling. Identifying the last ring date gives us the last known date that the tree was growing that produced the

timber. The date is *terminus post quem* because the timber did not include *sapwood* or a *bark* edge so we do not know how long afterwards the tree was felled.

However, oak has a predictable number of *sapwood* rings – and there are usually a minimum of 10 and a maximum of 55 *sapwood* rings present on British oak. This is known as the *sapwood range*. To discover the *terminus post quem* – the date after which the timber was felled – you must add 10 years onto the last known date on the tree ring sequence to reflect the minimum of 10 sapwood rings that would have been present.

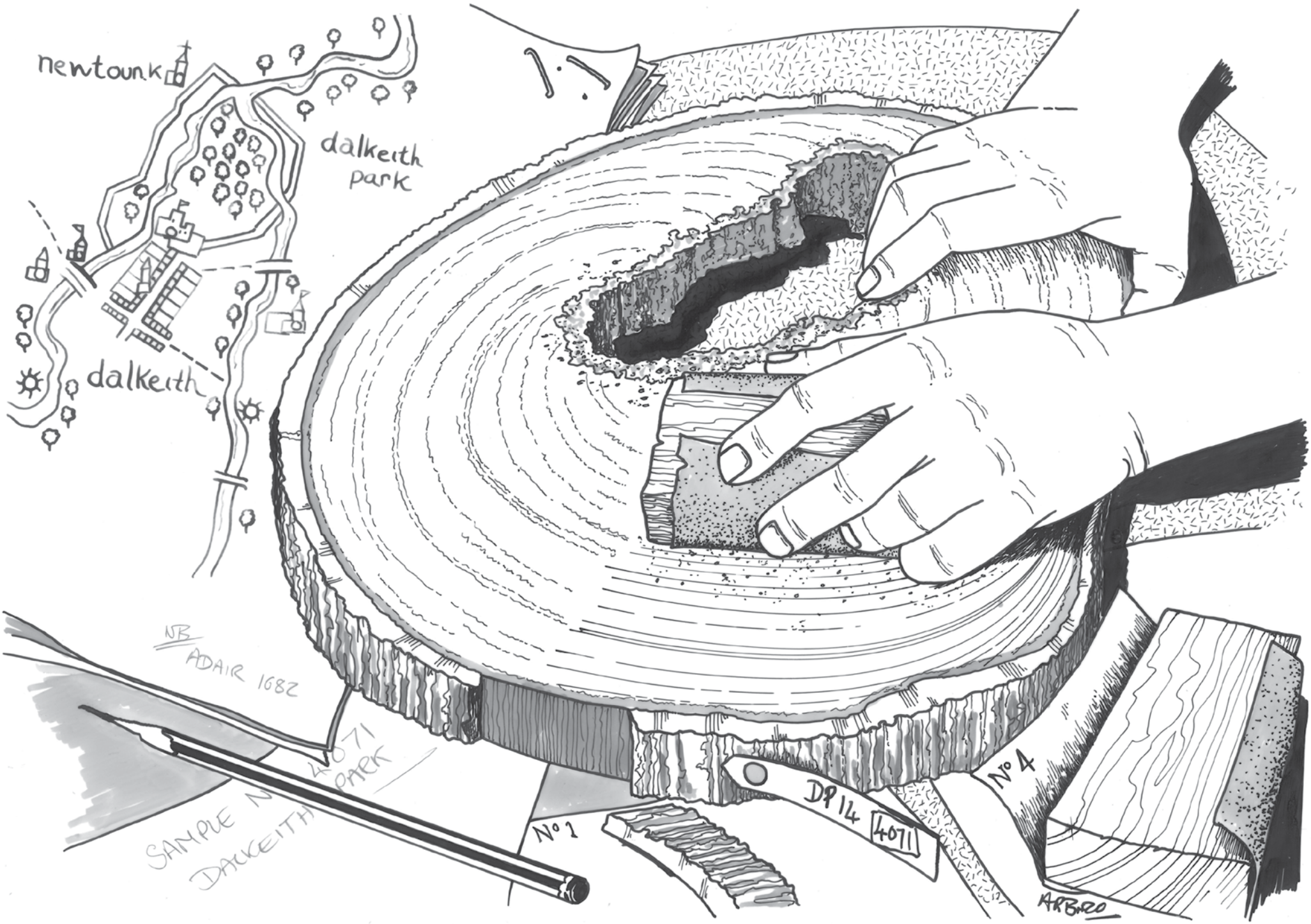
- What is the date of the earliest ring on your sample? (AD 1714)
- What is the date of the last ring for this timber? (AD 1748)
- What is the *terminus post quem* – the date after which the timber was felled? (AD 1758)
- Why is this a *terminus post quem*? (With no sapwood or bark preserved in the timber, dendrochronologists cannot identify the felling year or estimate the felling date range)
- What is a timber joist? (Joists are made from long timbers and are used in buildings to cross or span an area horizontally. They usually support a floor or ceiling)

Sample 5

Sample 5 comes from wide timber boards that are attached to the hallway of a house in the town. This form of interior decoration is known as 'Wainscot Panelling'. A photographic record and impression sample was taken from the oak panelling. There are 20 rings of *sapwood* preserved in the sample. Once you have matched the sample's **sequence graph** pattern to your *reference chronology* you can work out how old your sample is and use the dates discovered to learn more about the time period it comes from.

Ask your learners to date the archaeological sample using their *tree ring chronology*. There are 20 rings of *sapwood* preserved in the sample. We know that there are usually a minimum of 10 and a maximum of 55 *sapwood* rings present on British oak. This is known as the *sapwood range*. To work out the years in which the tree was probably felled (known as the *felling date range*) you need to calculate the maximum number of *sapwood* rings that could be missing and add them to the date of the last ring present.

- What is the date of the earliest ring on your sample? (AD 1750)
- What is the date of the last ring preserved on this board? (AD 1784)
- What is the *felling date range* of the sample? You will need to calculate the maximum number of sapwood rings that could be missing (35) and add them to the date of the last ring present. Can you work out the estimated *felling date range* of the timber?
  (AD 1784 + 35 = a *felling date range* of AD 1784 – 1819)
- What is Wainscot Panelling?
  (Wainscot Panelling is the name given to a type of interior decoration of the 17th and 18th centuries. Timber boards line the wall in hallways and rooms, sometimes just the lower half. The panels cover the stone walls and act as decoration and insulation. Originally the wide timber boards were only made from 'wainscot' oak, but the name stuck and is commonly used for all types of wood used to make this decorative panelling style)


newtounk
dalkeith park
dalkeith
NB
ADAIR 1682
SAMPLE N
DALKEITH
4071
PACK
No 1
DP 14
4071
No 4
ARBRO

Investigating the woodland history of Dalkeith

Using fallen ancient oaks from Dalkeith Park, and samples from living trees nearby, dendrochronologists have built a *reference chronology* that spans the years from AD 1592 to 2010. This has enabled a greater understanding of the woodland history of Dalkeith Park.

Historical sources indicate there has been woodland near Dalkeith since at least the 12th century, and Dalkeith Park itself was first recorded in 1542. Historic documents about Dalkeith Estate include contracts concerning the felling, planting and management of trees in the Estate.

Would the sampled ancient oaks correspond with known historical events? This was a rare opportunity to compare a *reference chronology* with documentary woodland history. The dendrochronologists were particularly keen to match *stem origin* dates (usually the sprouting date when a sapling starts to grow) with contracts regarding woodland management and other documentary evidence.

The results of the dendrochronological investigation revealed a range of *stem origin* dates which ranged through the 16th century, with a gap until the late 17th century, when another cluster of dates may reflect a phase of planting.

The oldest oaks that were sampled dated from the early to mid-16th century and were almost 500 years old! The presence of only three trees from this period amongst those sampled suggests that surviving trees of that age may be rare within the wood. Of the remaining samples, six dated from the late 16th to early 17th centuries, and twelve were from the late 17th century, indicating a period through much of the 17th century when few trees were planted.

The sampled trees were a mix of single stems (known as *maiden trees*) and multi-stem forms, and while the dates for the single stems indicate when they sprouted from their acorns, the stem origin dates for the multi-stems indicate when they were last *coppiced*.

Coppicing is a traditional woodland management technique which cuts the tree down to stimulate regrowth. When most broadleaf trees are cut back they regrow with multiple new stems. These straight stems can be useful for all sorts of things. But this means that the old multi-stem trees that were sampled and dated may be much older than their stem-dates indicate. The 16th century trees are a mixture of single stems and multi-stems, so some of those trees could be even older.

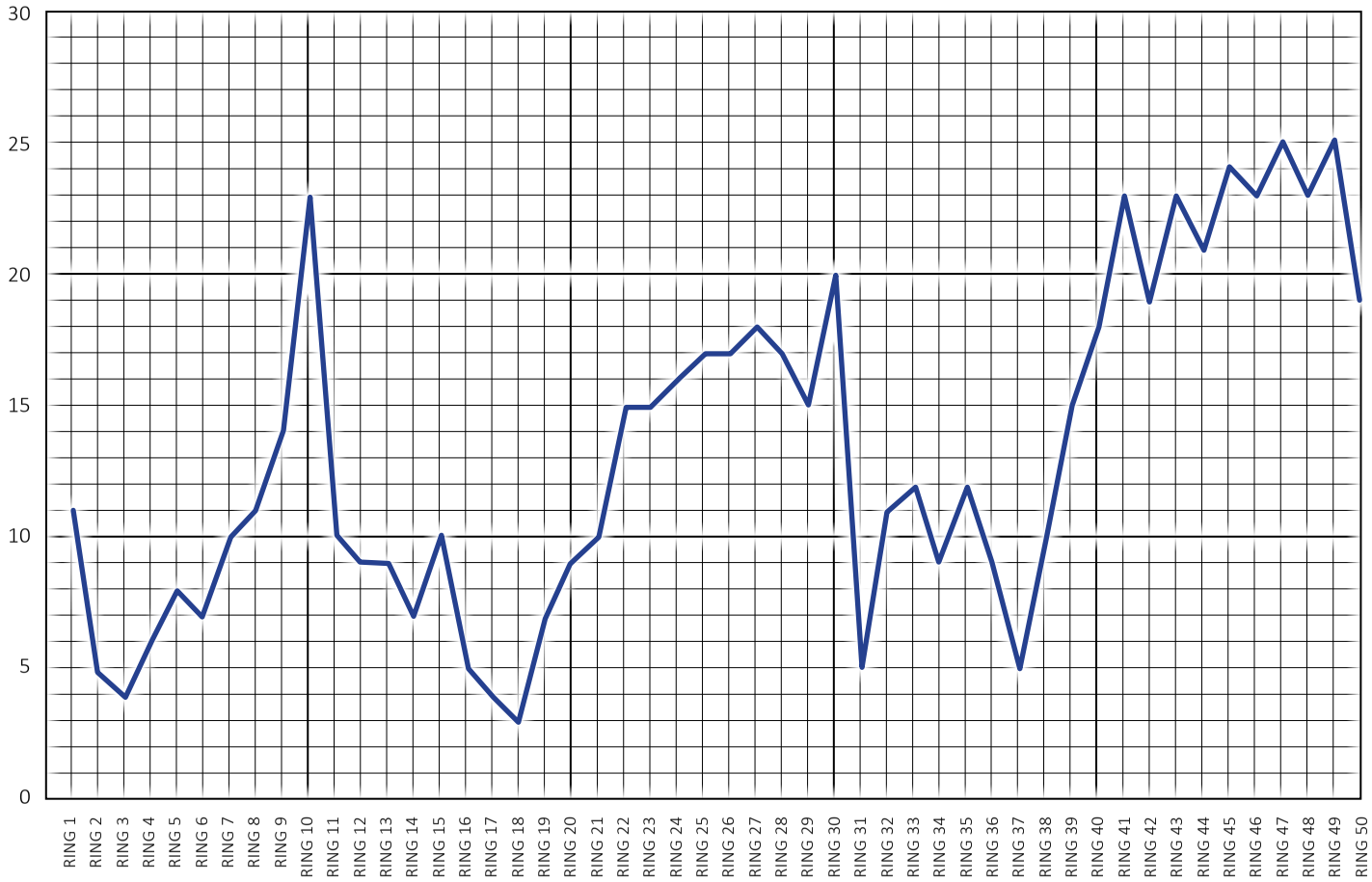
The earliest documented evidence of a park at Dalkeith is from 1542. Later in the 16th century, documents refer to the Castle and woods in Dalkeith being owned by the Earl of Morton, regent to the young James VI. There is documentary evidence of contracts issued for cutting trees in 1572-3 and 1577-8, to generate income for the Earl's fortification of Dalkeith Castle. One of these contracts stipulated that certain young trees and saplings be left to grow.

This felling of a substantial number of trees and the preservation of a few young trees may explain the survival of the three oldest among the sampled oaks, which would have been young trees at this time. There is also historical evidence for a period of exploitation of the wood for building projects in Edinburgh in the 17th century. Then a new owner, the Duchess of Buccleuch, invested heavily in the grounds and woods from the late 17th century, installing impressive formal landscape features. This work may have been when the late 17th century oaks, so prevalent in the samples taken for this study, were planted.

The dating of the old oaks at Dalkeith has allowed a greater understanding of the age and historical role of these woodlands as well as providing a new regional *reference chronology* for south east Scotland. This is now being extended back in time with samples from historic buildings and archaeological sites, adding to our dendrochronological jigsaw puzzle piece by piece.

Sequence graph recording sheet

D1



Sequence Table

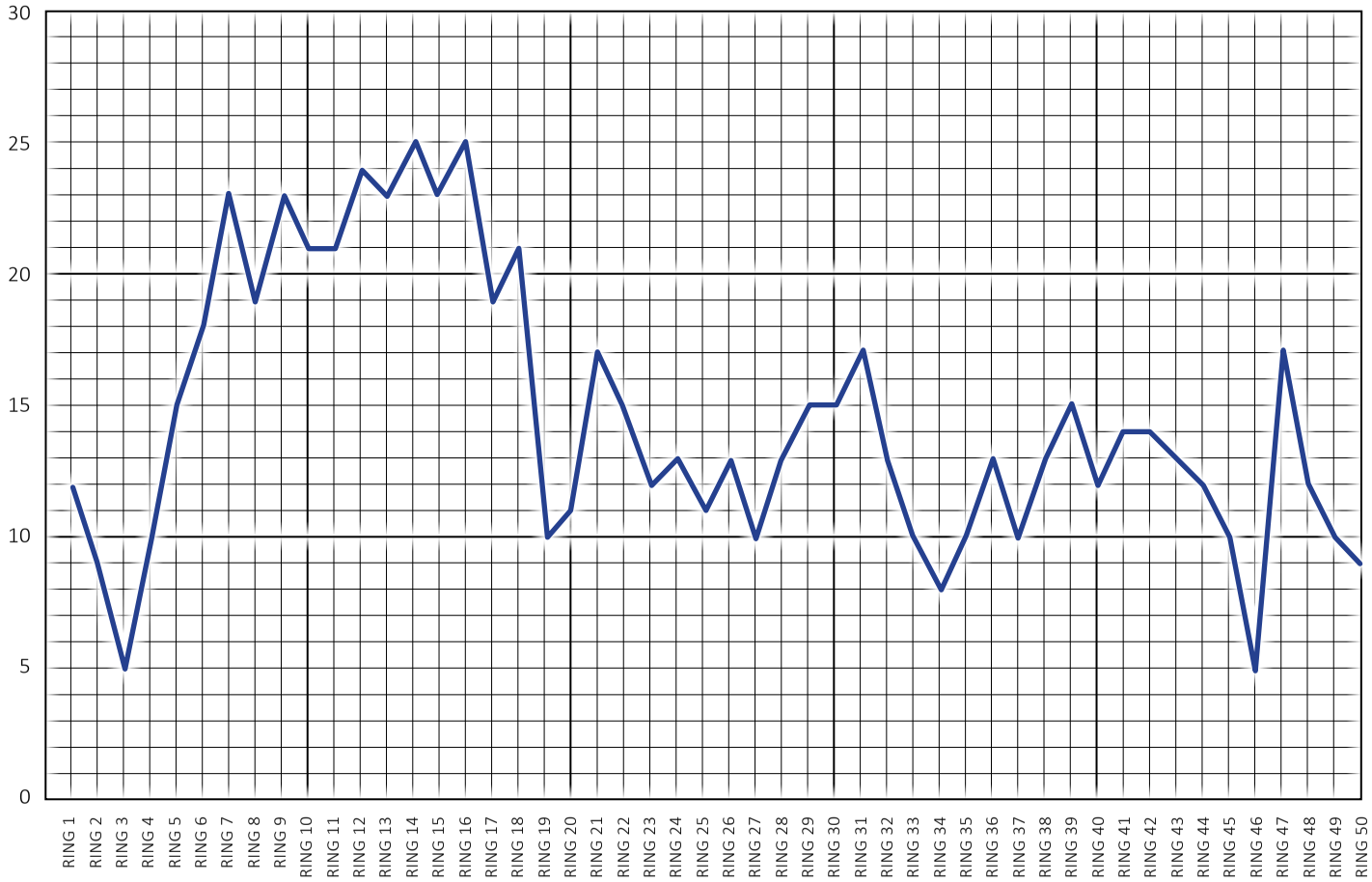
AD 823 - AD 872

Ring 1	11	Ring 11	10	Ring 21	10	Ring 31	5	Ring 41	23
Ring 2	5	Ring 12	9	Ring 22	15	Ring 32	11	Ring 42	19
Ring 3	4	Ring 13	9	Ring 23	15	Ring 33	12	Ring 43	23
Ring 4	6	Ring 14	7	Ring 24	16	Ring 34	9	Ring 44	21
Ring 5	8	Ring 15	10	Ring 25	17	Ring 35	12	Ring 45	24
Ring 6	7	Ring 16	5	Ring 26	17	Ring 36	9	Ring 46	23
Ring 7	10	Ring 17	4	Ring 27	18	Ring 37	5	Ring 47	25
Ring 8	11	Ring 18	3	Ring 28	17	Ring 38	10	Ring 48	23
Ring 9	14	Ring 19	7	Ring 29	15	Ring 39	15	Ring 49	25
Ring 10	23	Ring 20	9	Ring 30	20	Ring 40	18	Ring 50	19

Measurements in mm

Sequence graph recording sheet

E1



Sequence Table

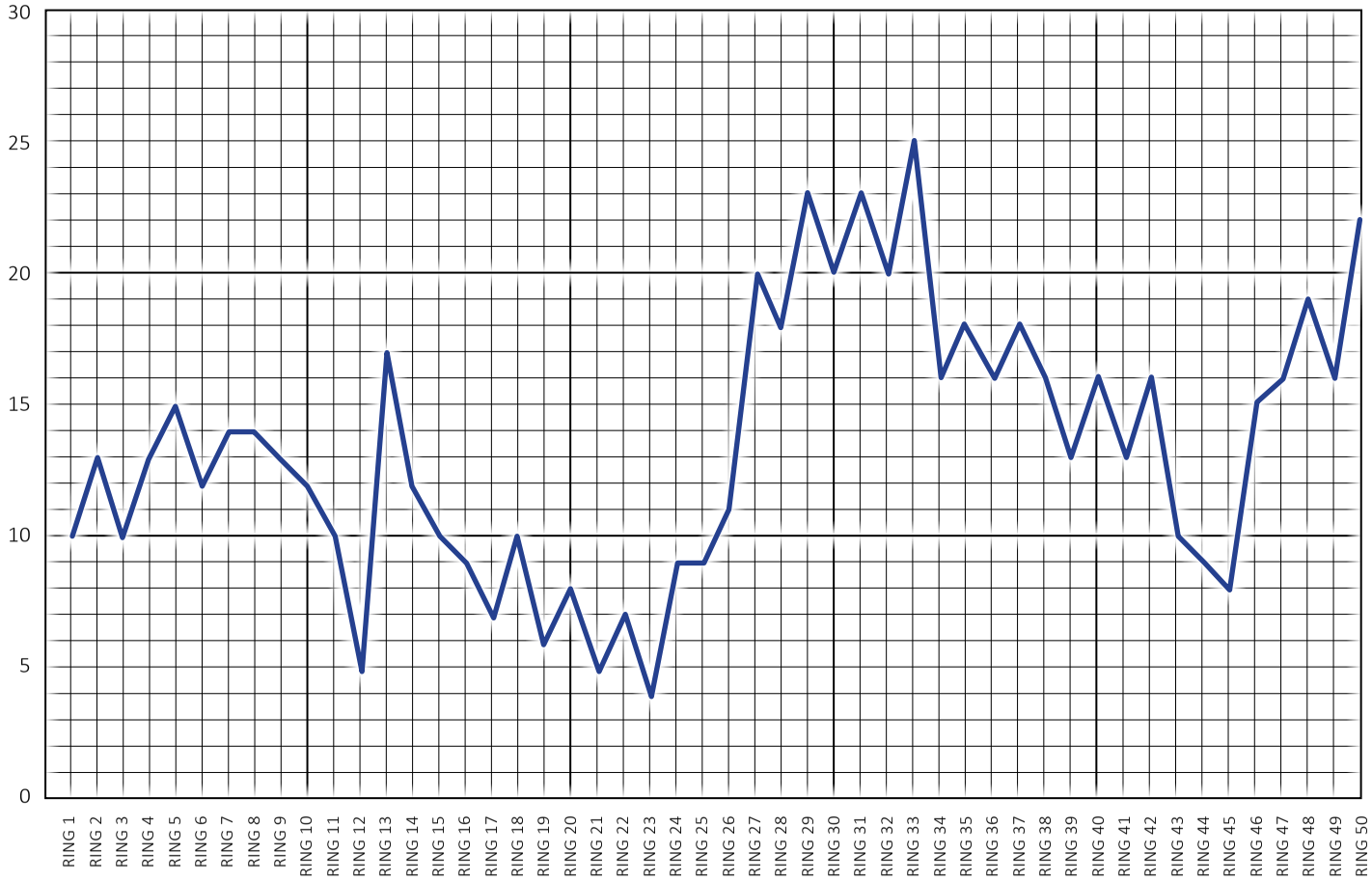
AD 857 - AD 906

Ring 1	12	Ring 11	21	Ring 21	17	Ring 31	17	Ring 41	14
Ring 2	9	Ring 12	24	Ring 22	15	Ring 32	13	Ring 42	14
Ring 3	5	Ring 13	23	Ring 23	12	Ring 33	10	Ring 43	13
Ring 4	10	Ring 14	25	Ring 24	13	Ring 34	8	Ring 44	12
Ring 5	15	Ring 15	23	Ring 25	11	Ring 35	10	Ring 45	10
Ring 6	18	Ring 16	25	Ring 26	13	Ring 36	13	Ring 46	5
Ring 7	23	Ring 17	19	Ring 27	10	Ring 37	10	Ring 47	17
Ring 8	19	Ring 18	21	Ring 28	13	Ring 38	13	Ring 48	12
Ring 9	23	Ring 19	10	Ring 29	15	Ring 39	15	Ring 49	10
Ring 10	21	Ring 20	11	Ring 30	15	Ring 40	12	Ring 50	9

Measurements in mm

Sequence graph recording sheet

N1



Sequence Table

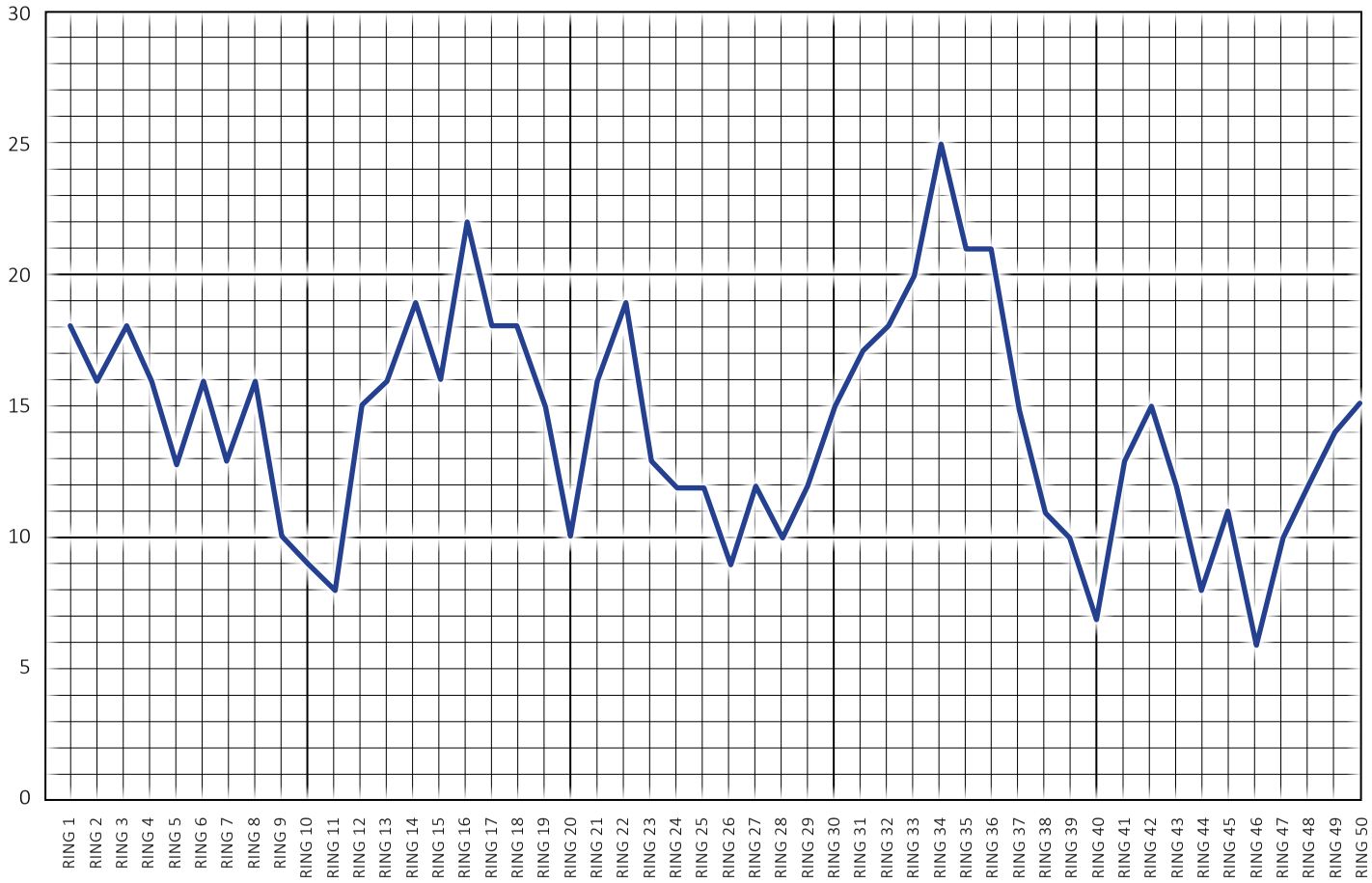
AD 891 - AD 940

Ring 1	10	Ring 11	10	Ring 21	5	Ring 31	23	Ring 41	13
Ring 2	13	Ring 12	5	Ring 22	7	Ring 32	20	Ring 42	16
Ring 3	10	Ring 13	17	Ring 23	4	Ring 33	25	Ring 43	10
Ring 4	13	Ring 14	12	Ring 24	9	Ring 34	16	Ring 44	9
Ring 5	15	Ring 15	10	Ring 25	9	Ring 35	18	Ring 45	8
Ring 6	12	Ring 16	9	Ring 26	11	Ring 36	16	Ring 46	15
Ring 7	14	Ring 17	7	Ring 27	20	Ring 37	18	Ring 47	16
Ring 8	14	Ring 18	10	Ring 28	18	Ring 38	16	Ring 48	19
Ring 9	13	Ring 19	6	Ring 29	23	Ring 39	13	Ring 49	16
Ring 10	12	Ring 20	8	Ring 30	20	Ring 40	16	Ring 50	22

Measurements in mm

Sequence graph recording sheet

D2



Sequence Table

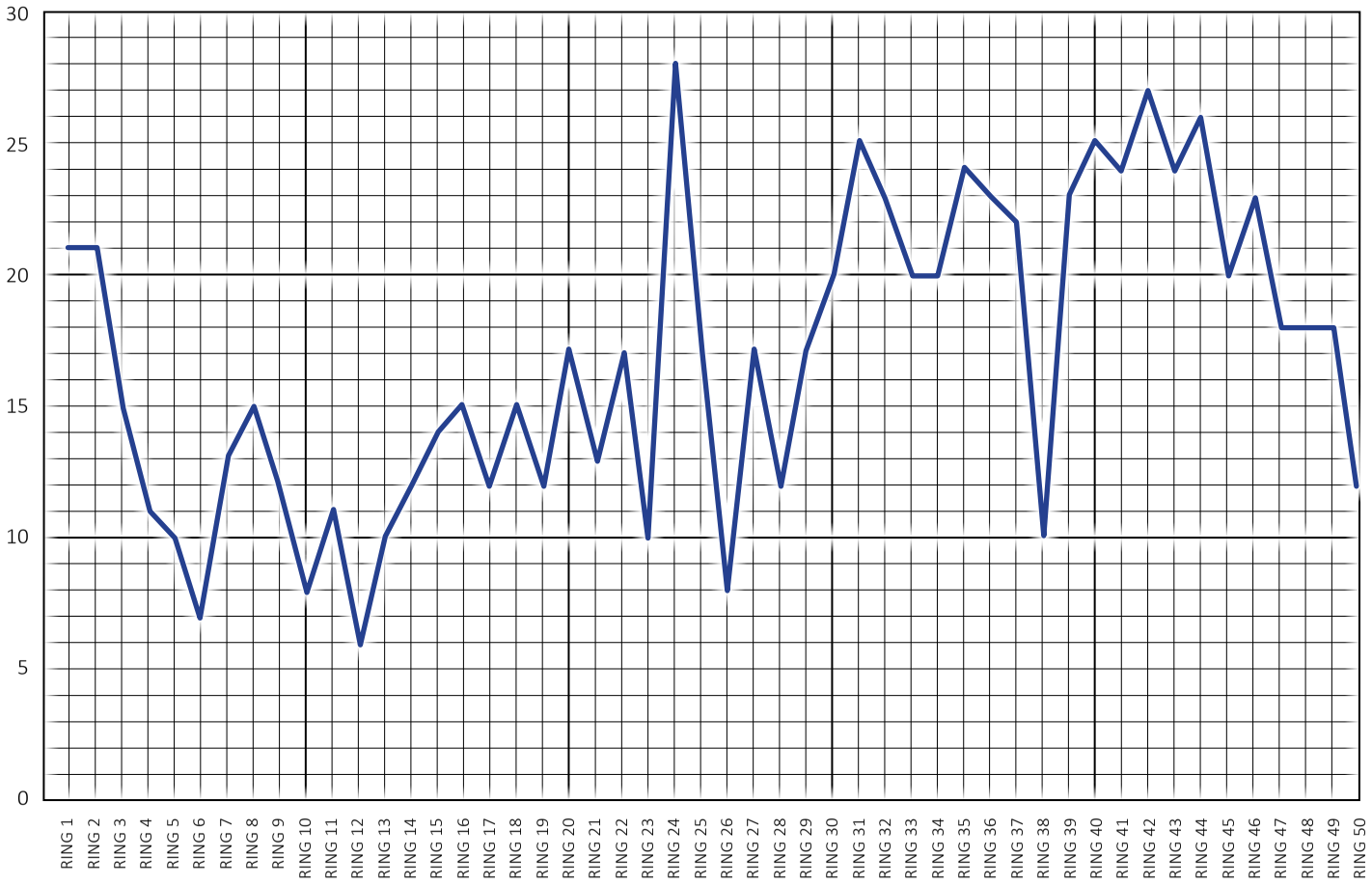
AD 925 - AD 974

Ring 1	12	Ring 11	24	Ring 21	17	Ring 31	17	Ring 41	14
Ring 2	9	Ring 12	23	Ring 22	15	Ring 32	13	Ring 42	14
Ring 3	5	Ring 13	25	Ring 23	12	Ring 33	10	Ring 43	13
Ring 4	10	Ring 14	23	Ring 24	13	Ring 34	8	Ring 44	12
Ring 5	15	Ring 15	25	Ring 25	11	Ring 35	10	Ring 45	10
Ring 6	18	Ring 16	19	Ring 26	13	Ring 36	13	Ring 46	5
Ring 7	23	Ring 17	21	Ring 27	10	Ring 37	10	Ring 47	17
Ring 8	19	Ring 18	10	Ring 28	13	Ring 38	13	Ring 48	12
Ring 9	23	Ring 19	11	Ring 29	15	Ring 39	15	Ring 49	10
Ring 10	21	Ring 20	15	Ring 30	15	Ring 40	12	Ring 50	9

Measurements in mm

Sequence graph recording sheet

R1



Sequence Table

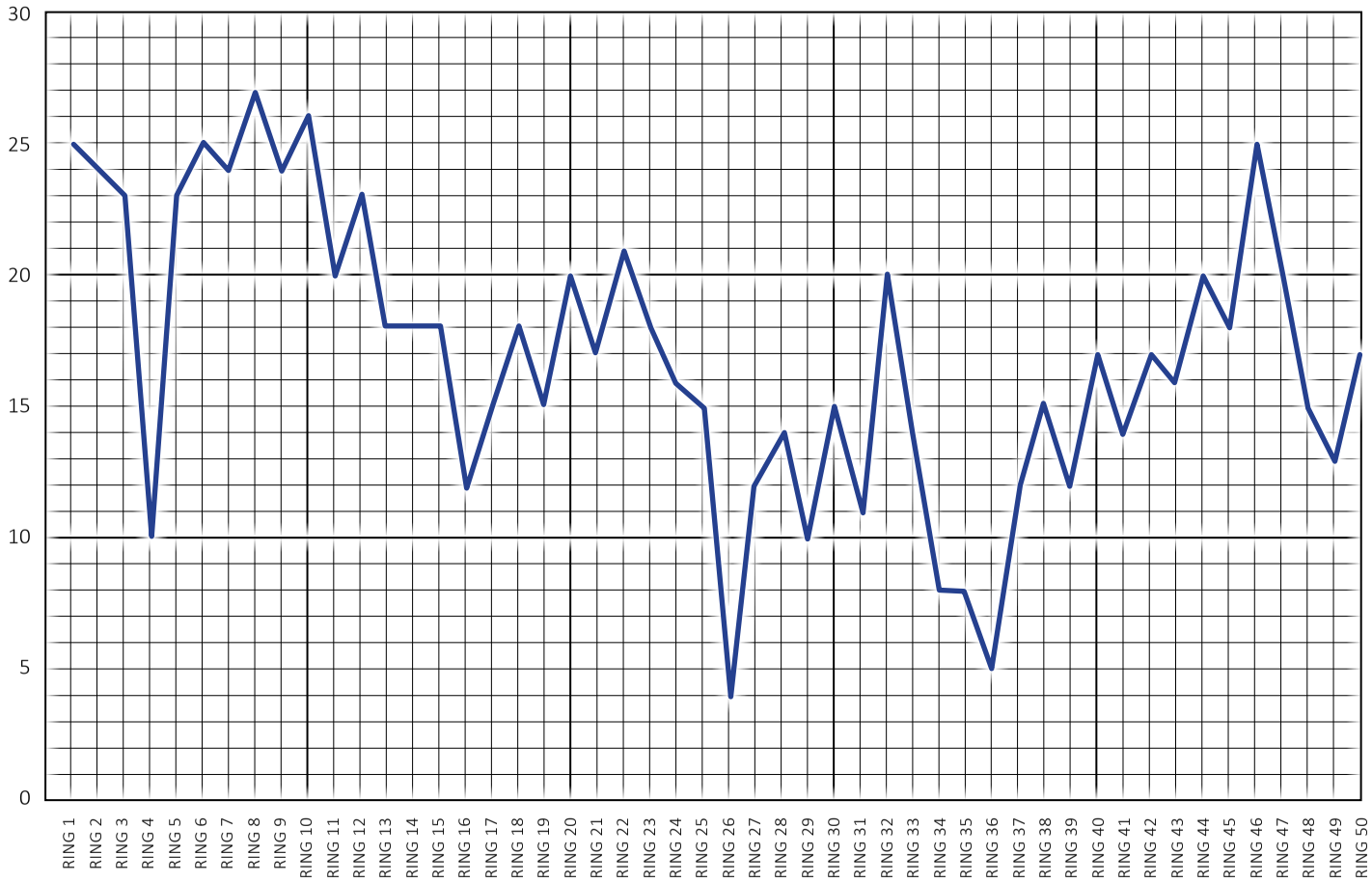
AD 959 - AD 1008

Ring 1	21	Ring 11	11	Ring 21	13	Ring 31	25	Ring 41	24
Ring 2	21	Ring 12	6	Ring 22	17	Ring 32	23	Ring 42	27
Ring 3	15	Ring 13	10	Ring 23	10	Ring 33	20	Ring 43	24
Ring 4	11	Ring 14	12	Ring 24	28	Ring 34	20	Ring 44	26
Ring 5	10	Ring 15	14	Ring 25	17	Ring 35	24	Ring 45	20
Ring 6	7	Ring 16	15	Ring 26	8	Ring 36	23	Ring 46	23
Ring 7	13	Ring 17	12	Ring 27	17	Ring 37	22	Ring 47	18
Ring 8	15	Ring 18	15	Ring 28	12	Ring 38	10	Ring 48	18
Ring 9	12	Ring 19	12	Ring 29	17	Ring 39	23	Ring 49	18
Ring 10	8	Ring 20	17	Ring 30	20	Ring 40	25	Ring 50	12

Measurements in mm

Sequence graph recording sheet

O1



Sequence Table

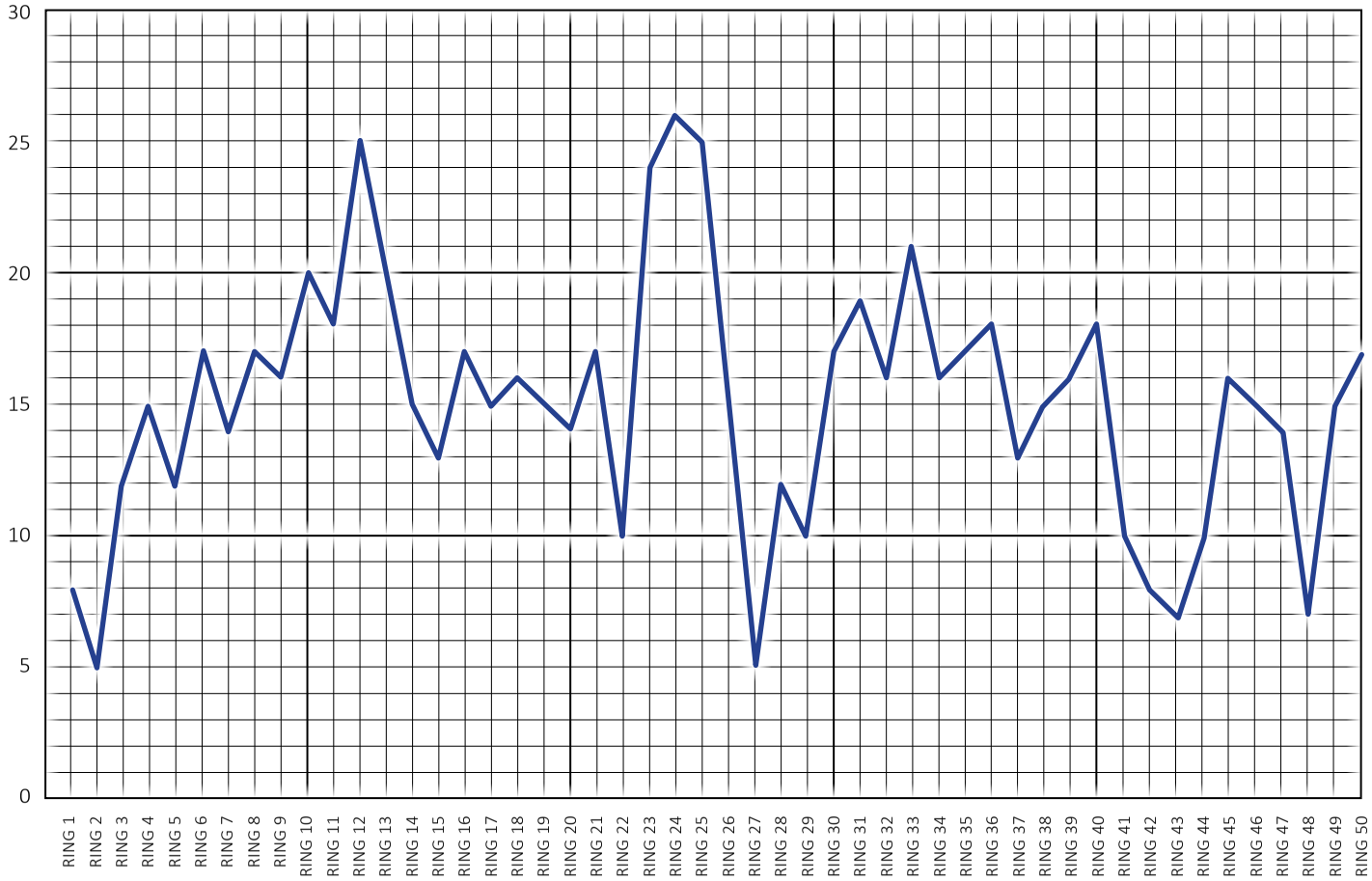
AD 993 - AD 1042

Ring 1	24	Ring 11	20	Ring 21	17	Ring 31	11	Ring 41	14
Ring 2	23	Ring 12	23	Ring 22	21	Ring 32	20	Ring 42	17
Ring 3	22	Ring 13	18	Ring 23	18	Ring 33	14	Ring 43	16
Ring 4	10	Ring 14	18	Ring 24	16	Ring 34	8	Ring 44	20
Ring 5	23	Ring 15	18	Ring 25	15	Ring 35	8	Ring 45	18
Ring 6	25	Ring 16	12	Ring 26	4	Ring 36	5	Ring 46	25
Ring 7	24	Ring 17	15	Ring 27	12	Ring 37	12	Ring 47	20
Ring 8	27	Ring 18	18	Ring 28	14	Ring 38	15	Ring 48	15
Ring 9	24	Ring 19	15	Ring 29	10	Ring 39	12	Ring 49	13
Ring 10	26	Ring 20	20	Ring 30	15	Ring 40	17	Ring 50	17

Measurements in mm

Sequence graph recording sheet

C1



Sequence Table

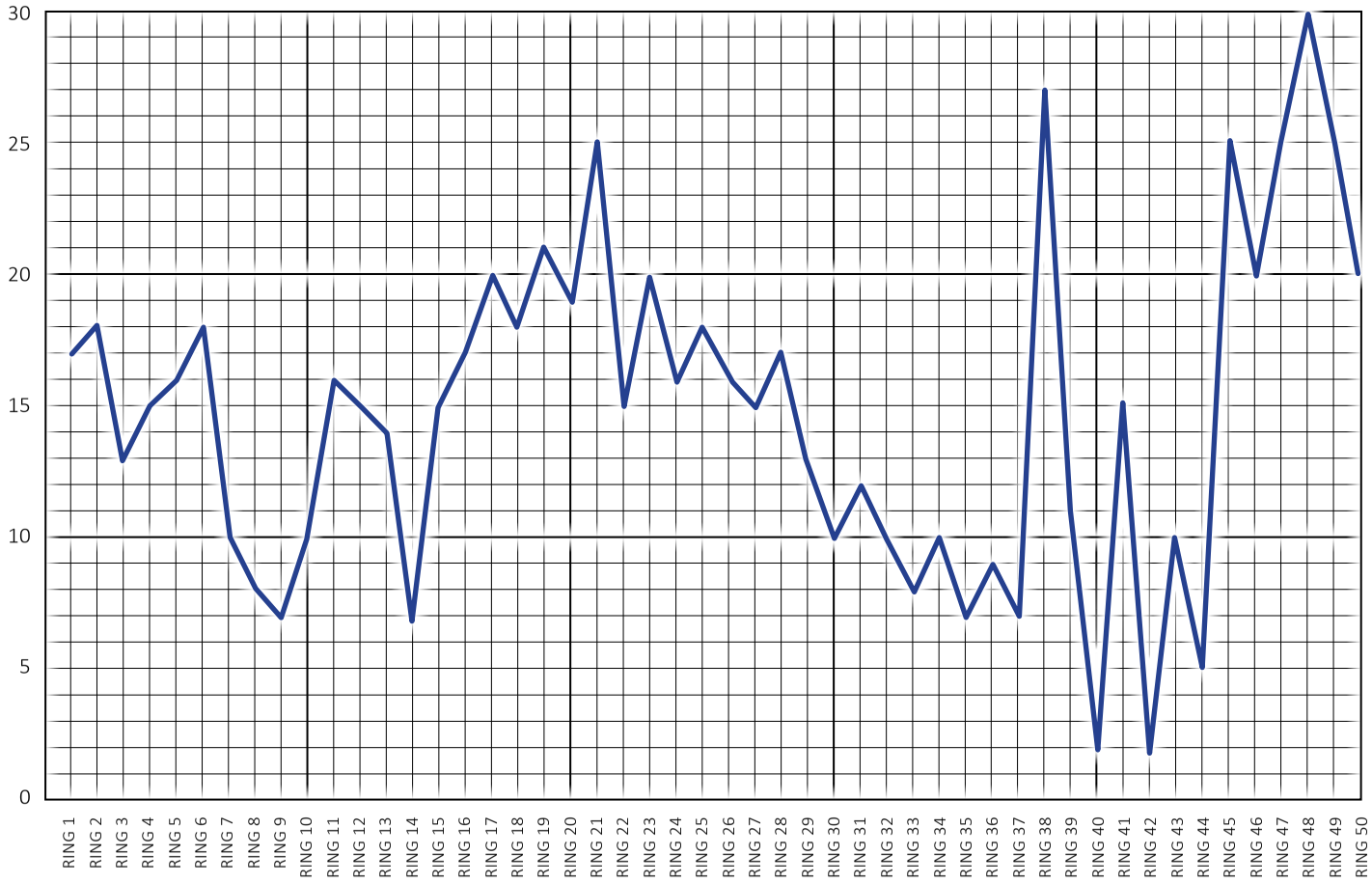
AD 1027 - AD 1076

Ring 1	8	Ring 11	18	Ring 21	17	Ring 31	19	Ring 41	10
Ring 2	5	Ring 12	25	Ring 22	10	Ring 32	16	Ring 42	8
Ring 3	12	Ring 13	20	Ring 23	24	Ring 33	21	Ring 43	7
Ring 4	15	Ring 14	15	Ring 24	26	Ring 34	16	Ring 44	10
Ring 5	12	Ring 15	13	Ring 25	25	Ring 35	17	Ring 45	16
Ring 6	17	Ring 16	17	Ring 26	16	Ring 36	18	Ring 46	15
Ring 7	14	Ring 17	15	Ring 27	5	Ring 37	13	Ring 47	14
Ring 8	17	Ring 18	16	Ring 28	12	Ring 38	15	Ring 48	7
Ring 9	16	Ring 19	15	Ring 29	10	Ring 39	16	Ring 49	15
Ring 10	20	Ring 20	14	Ring 30	17	Ring 40	18	Ring 50	17

Measurements in mm

Sequence graph recording sheet

H1



Sequence Table

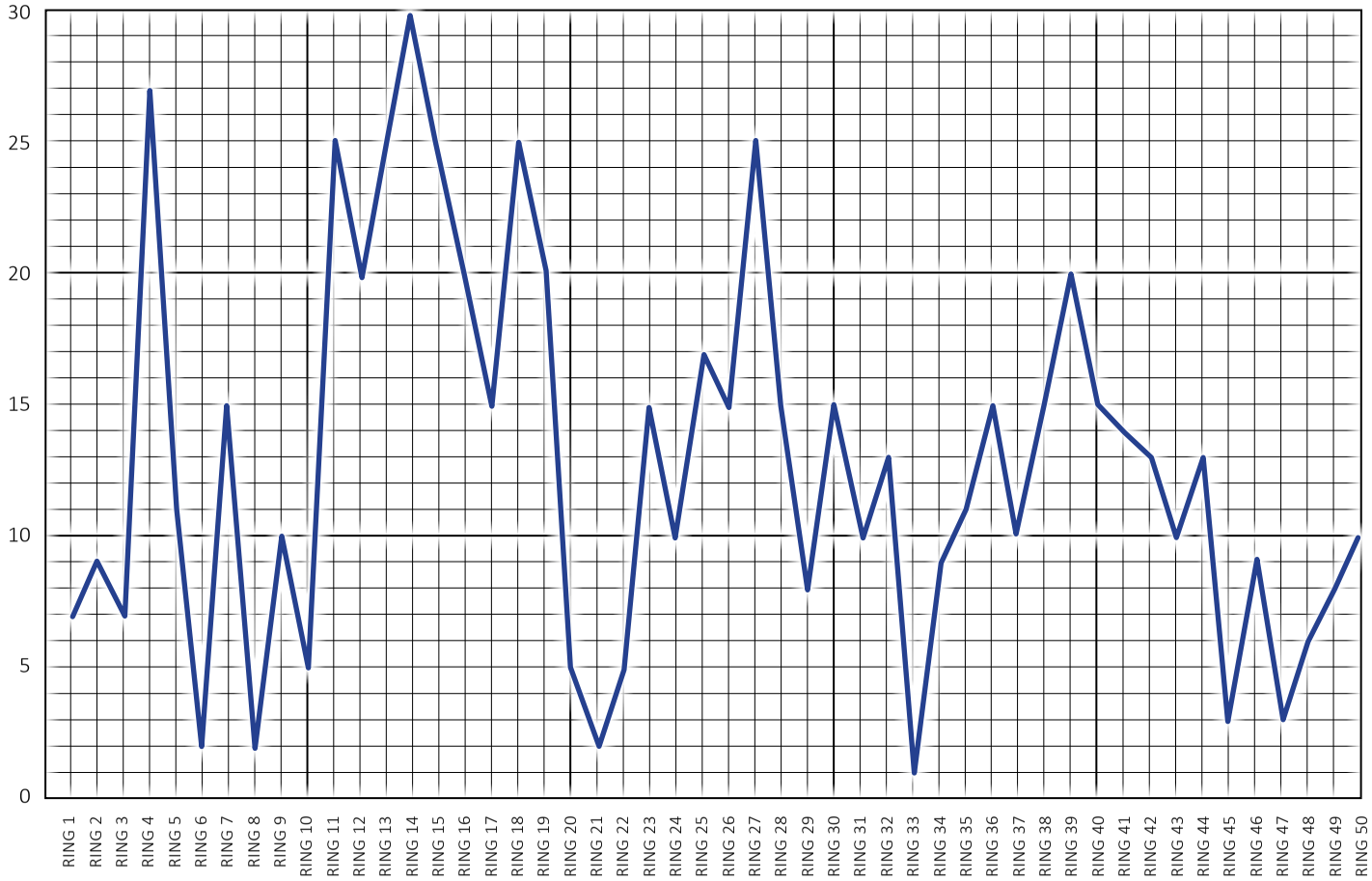
AD 1061 - AD 1110

Ring 1	17	Ring 11	16	Ring 21	25	Ring 31	12	Ring 41	15
Ring 2	18	Ring 12	15	Ring 22	15	Ring 32	10	Ring 42	2
Ring 3	13	Ring 13	14	Ring 23	20	Ring 33	8	Ring 43	10
Ring 4	15	Ring 14	7	Ring 24	16	Ring 34	10	Ring 44	5
Ring 5	16	Ring 15	15	Ring 25	18	Ring 35	7	Ring 45	25
Ring 6	18	Ring 16	17	Ring 26	16	Ring 36	9	Ring 46	20
Ring 7	10	Ring 17	20	Ring 27	15	Ring 37	7	Ring 47	25
Ring 8	8	Ring 18	18	Ring 28	17	Ring 38	27	Ring 48	30
Ring 9	7	Ring 19	21	Ring 29	13	Ring 39	11	Ring 49	25
Ring 10	10	Ring 20	19	Ring 30	10	Ring 40	2	Ring 50	20

Measurements in mm

Sequence graph recording sheet

R2



Sequence Table

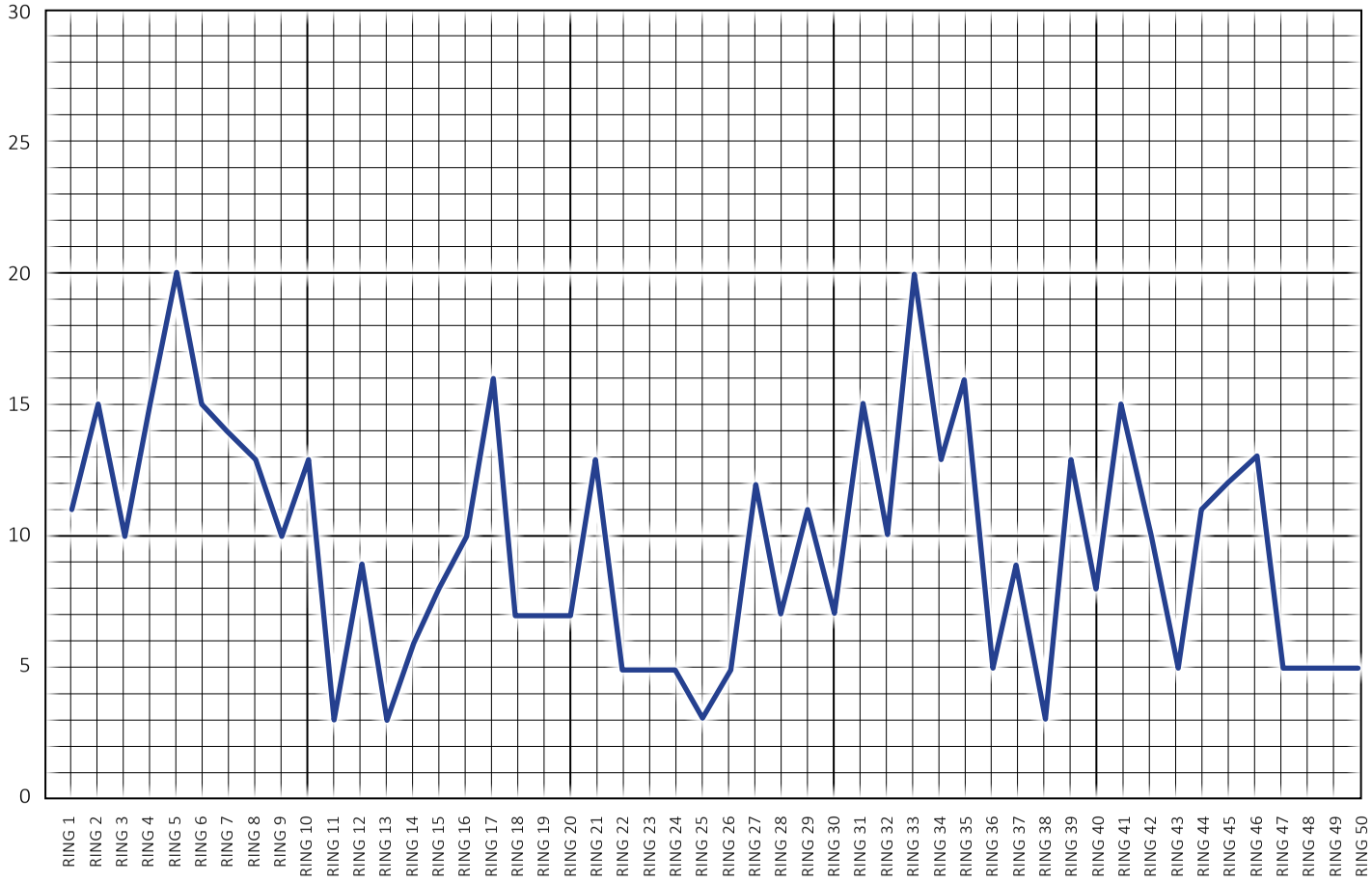
AD 1095 - AD 1144

Ring 1	7	Ring 11	25	Ring 21	2	Ring 31	10	Ring 41	14
Ring 2	9	Ring 12	20	Ring 22	5	Ring 32	13	Ring 42	13
Ring 3	7	Ring 13	25	Ring 23	15	Ring 33	1	Ring 43	10
Ring 4	27	Ring 14	30	Ring 24	10	Ring 34	9	Ring 44	13
Ring 5	11	Ring 15	25	Ring 25	17	Ring 35	11	Ring 45	3
Ring 6	2	Ring 16	20	Ring 26	15	Ring 36	15	Ring 46	9
Ring 7	15	Ring 17	15	Ring 27	25	Ring 37	10	Ring 47	3
Ring 8	2	Ring 18	25	Ring 28	15	Ring 38	15	Ring 48	6
Ring 9	10	Ring 19	20	Ring 29	8	Ring 39	20	Ring 49	8
Ring 10	5	Ring 20	5	Ring 30	15	Ring 40	15	Ring 50	10

Measurements in mm

Sequence graph recording sheet

O2



Sequence Table

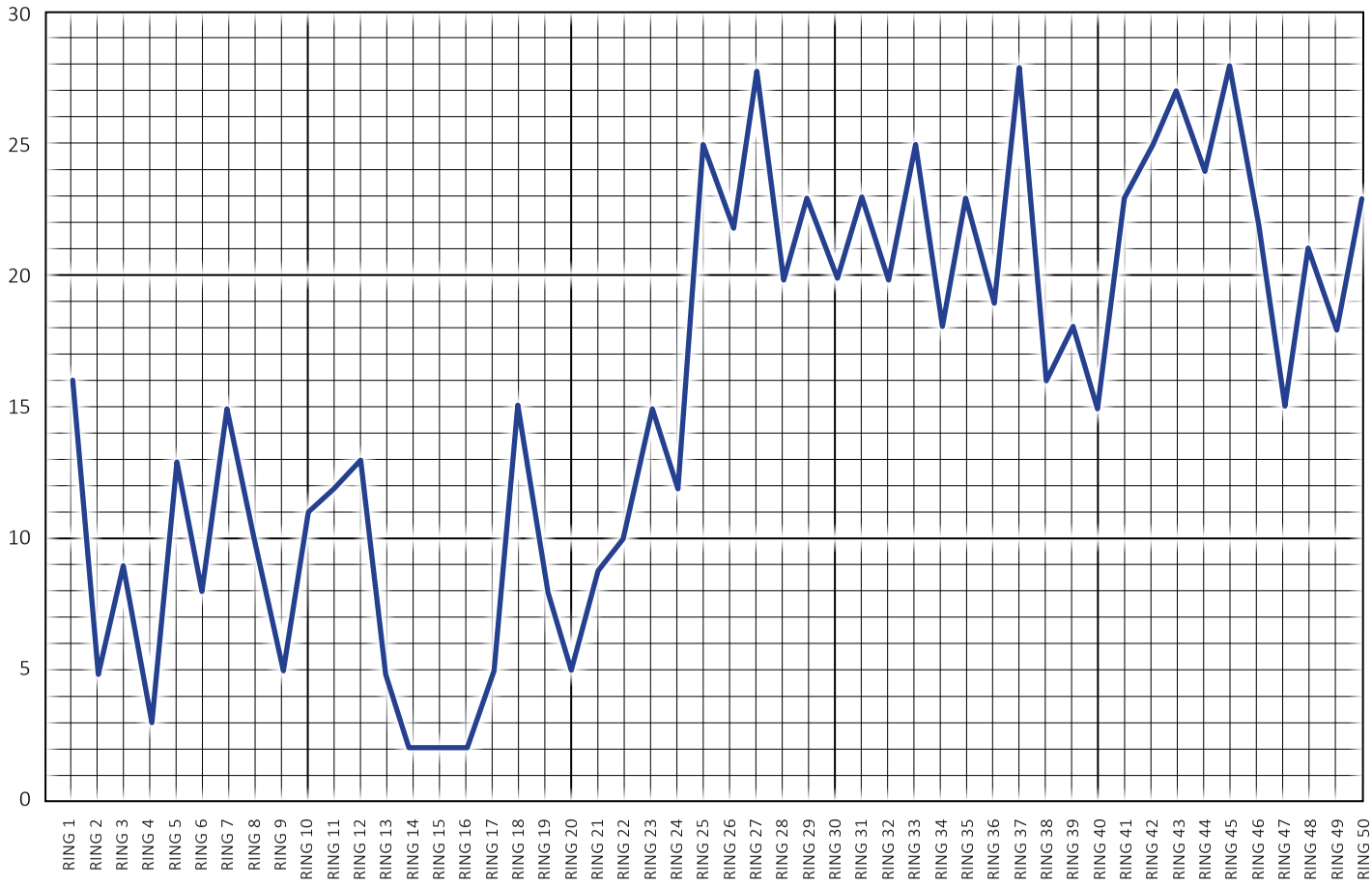
AD 1129 - AD 1178

Ring 1	11	Ring 11	3	Ring 21	13	Ring 31	15	Ring 41	15
Ring 2	15	Ring 12	9	Ring 22	5	Ring 32	10	Ring 42	10
Ring 3	10	Ring 13	3	Ring 23	5	Ring 33	20	Ring 43	5
Ring 4	15	Ring 14	6	Ring 24	5	Ring 34	13	Ring 44	11
Ring 5	20	Ring 15	8	Ring 25	3	Ring 35	16	Ring 45	12
Ring 6	15	Ring 16	10	Ring 26	5	Ring 36	5	Ring 46	13
Ring 7	14	Ring 17	16	Ring 27	12	Ring 37	9	Ring 47	5
Ring 8	13	Ring 18	7	Ring 28	7	Ring 38	3	Ring 48	2
Ring 9	10	Ring 19	7	Ring 29	11	Ring 39	13	Ring 49	2
Ring 10	13	Ring 20	7	Ring 30	7	Ring 40	8	Ring 50	2

Measurements in mm

Sequence graph recording sheet

N2



Sequence Table

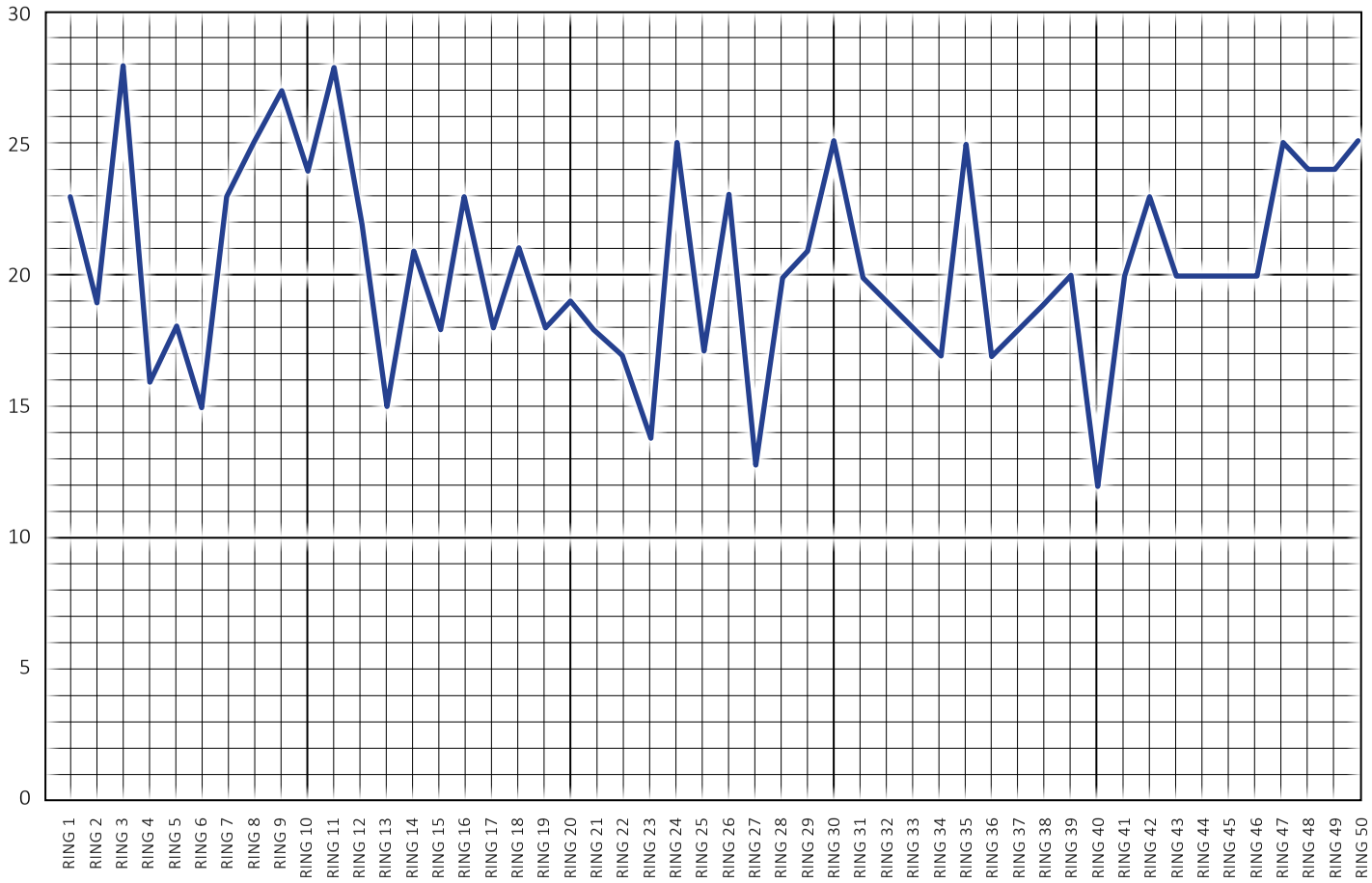
AD 1163 - AD 1212

Ring 1	16	Ring 11	12	Ring 21	9	Ring 31	23	Ring 41	23
Ring 2	5	Ring 12	13	Ring 22	10	Ring 32	20	Ring 42	25
Ring 3	9	Ring 13	5	Ring 23	15	Ring 33	25	Ring 43	27
Ring 4	3	Ring 14	2	Ring 24	12	Ring 34	17	Ring 44	24
Ring 5	13	Ring 15	2	Ring 25	25	Ring 35	23	Ring 45	28
Ring 6	8	Ring 16	2	Ring 26	22	Ring 36	19	Ring 46	22
Ring 7	15	Ring 17	5	Ring 27	28	Ring 37	28	Ring 47	15
Ring 8	10	Ring 18	15	Ring 28	20	Ring 38	16	Ring 48	21
Ring 9	5	Ring 19	8	Ring 29	23	Ring 39	18	Ring 49	18
Ring 10	11	Ring 20	5	Ring 30	20	Ring 40	15	Ring 50	23

Measurements in mm

Sequence graph recording sheet

O3



Sequence Table

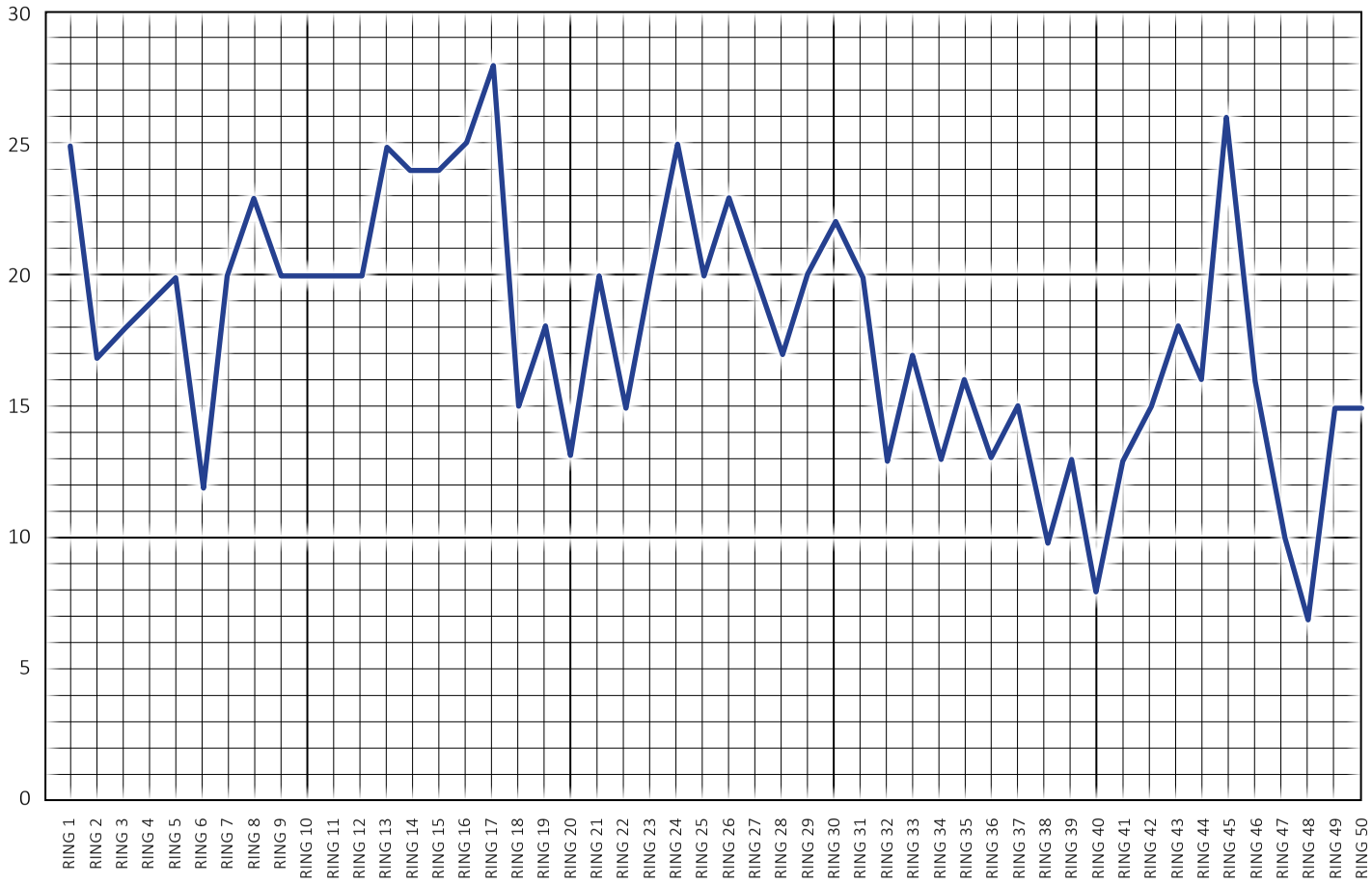
AD 1197 - AD 1246

Ring 1	23	Ring 11	28	Ring 21	18	Ring 31	20	Ring 41	20
Ring 2	19	Ring 12	22	Ring 22	17	Ring 32	19	Ring 42	23
Ring 3	28	Ring 13	15	Ring 23	14	Ring 33	18	Ring 43	20
Ring 4	16	Ring 14	21	Ring 24	25	Ring 34	17	Ring 44	20
Ring 5	18	Ring 15	18	Ring 25	17	Ring 35	25	Ring 45	20
Ring 6	15	Ring 16	23	Ring 26	23	Ring 36	17	Ring 46	20
Ring 7	23	Ring 17	18	Ring 27	13	Ring 37	18	Ring 47	25
Ring 8	25	Ring 18	21	Ring 28	20	Ring 38	19	Ring 48	24
Ring 9	27	Ring 19	18	Ring 29	21	Ring 39	20	Ring 49	24
Ring 10	24	Ring 20	19	Ring 30	25	Ring 40	12	Ring 50	25

Measurements in mm

Sequence graph recording sheet

L1



Sequence Table

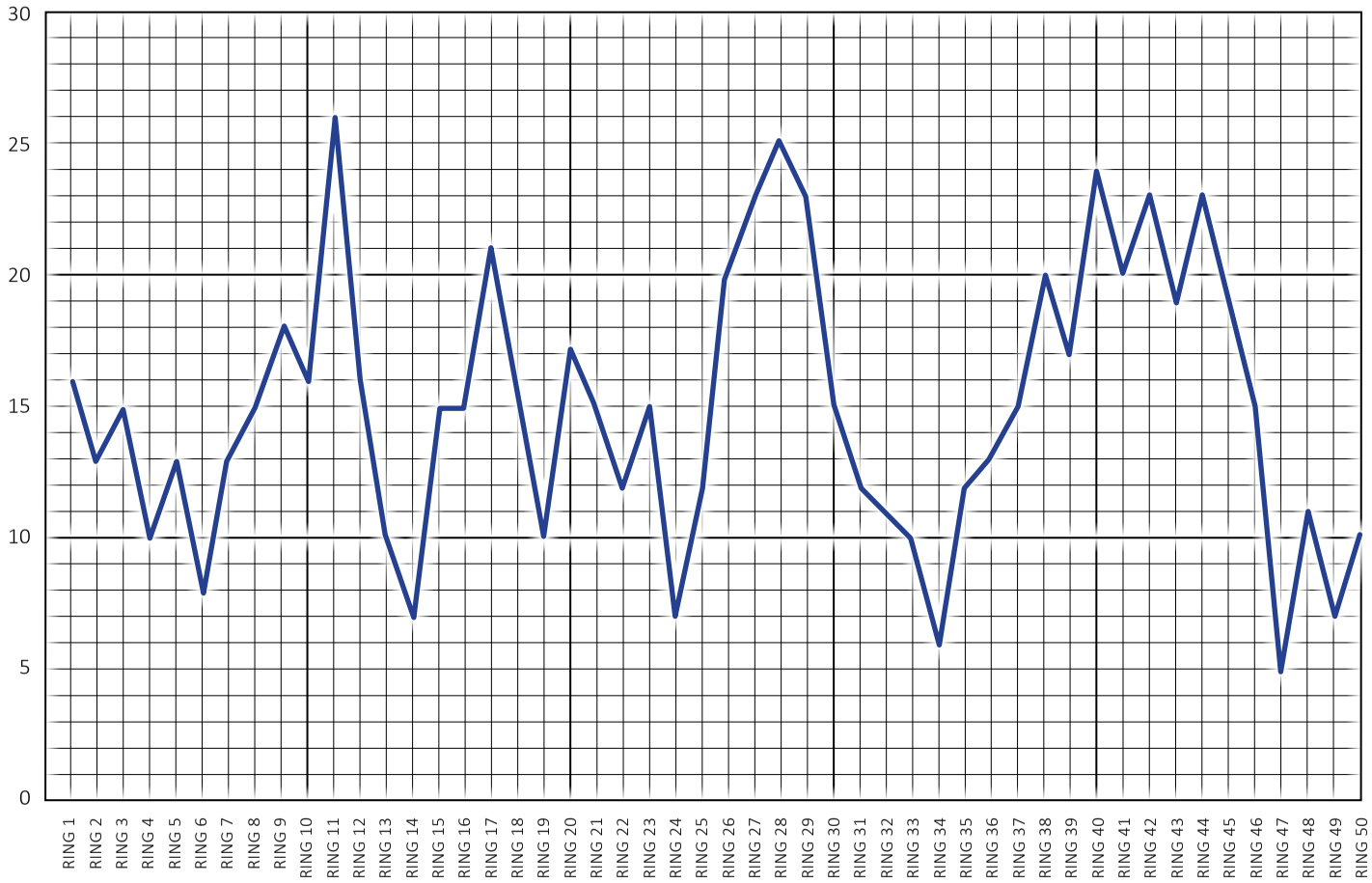
AD 1231 - AD 1280

Ring 1	25	Ring 11	20	Ring 21	20	Ring 31	20	Ring 41	13
Ring 2	17	Ring 12	20	Ring 22	15	Ring 32	13	Ring 42	15
Ring 3	18	Ring 13	25	Ring 23	20	Ring 33	17	Ring 43	18
Ring 4	19	Ring 14	24	Ring 24	25	Ring 34	13	Ring 44	16
Ring 5	20	Ring 15	24	Ring 25	20	Ring 35	16	Ring 45	26
Ring 6	12	Ring 16	25	Ring 26	23	Ring 36	13	Ring 46	16
Ring 7	20	Ring 17	28	Ring 27	20	Ring 37	15	Ring 47	10
Ring 8	23	Ring 18	15	Ring 28	17	Ring 38	10	Ring 48	7
Ring 9	20	Ring 19	18	Ring 29	20	Ring 39	13	Ring 49	15
Ring 10	20	Ring 20	13	Ring 30	22	Ring 40	8	Ring 50	15

Measurements in mm

Sequence graph recording sheet

O4



Sequence Table

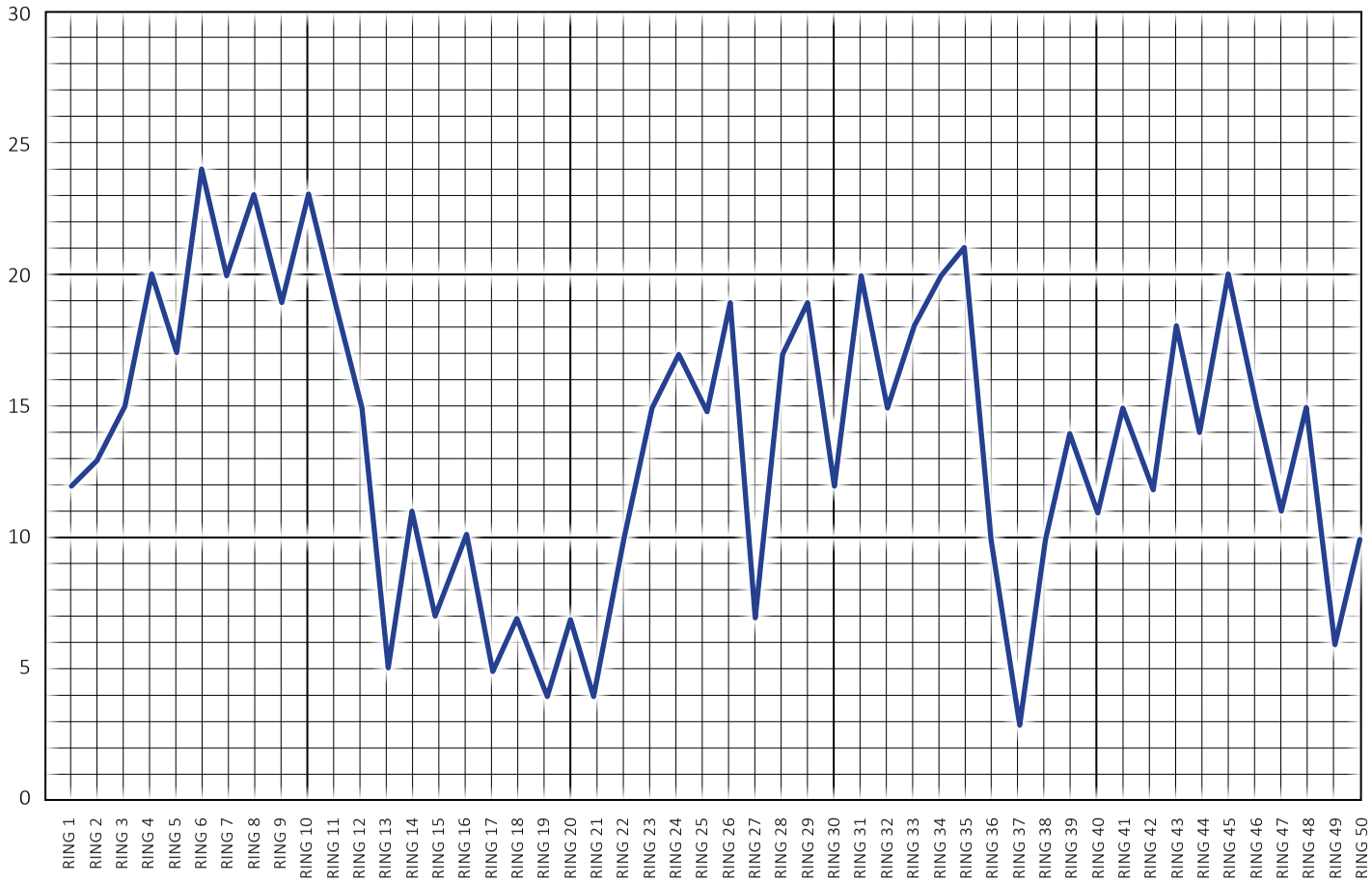
AD 1265 - AD 1314

Ring 1	16	Ring 11	26	Ring 21	15	Ring 31	12	Ring 41	20
Ring 2	13	Ring 12	16	Ring 22	12	Ring 32	11	Ring 42	23
Ring 3	15	Ring 13	10	Ring 23	15	Ring 33	10	Ring 43	19
Ring 4	10	Ring 14	7	Ring 24	7	Ring 34	6	Ring 44	23
Ring 5	13	Ring 15	15	Ring 25	12	Ring 35	12	Ring 45	19
Ring 6	8	Ring 16	15	Ring 26	20	Ring 36	13	Ring 46	15
Ring 7	13	Ring 17	21	Ring 27	23	Ring 37	15	Ring 47	5
Ring 8	15	Ring 18	15	Ring 28	25	Ring 38	20	Ring 48	11
Ring 9	18	Ring 19	10	Ring 29	23	Ring 39	17	Ring 49	7
Ring 10	16	Ring 20	17	Ring 30	15	Ring 40	24	Ring 50	10

Measurements in mm

Sequence graph recording sheet

G1



Sequence Table

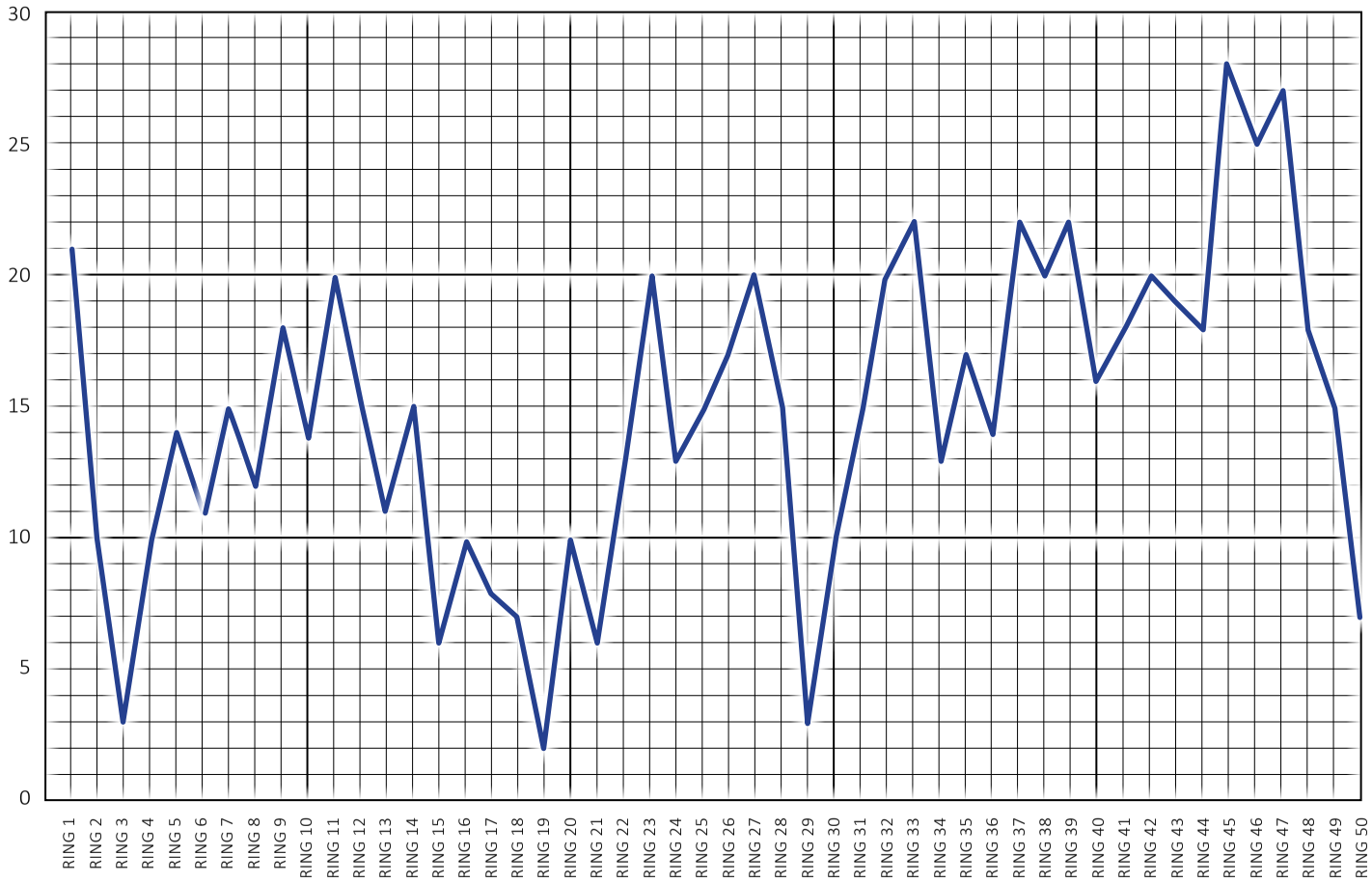
AD 1299 - AD 1348

Ring 1	12	Ring 11	19	Ring 21	4	Ring 31	20	Ring 41	15
Ring 2	13	Ring 12	15	Ring 22	10	Ring 32	15	Ring 42	12
Ring 3	15	Ring 13	5	Ring 23	15	Ring 33	18	Ring 43	18
Ring 4	20	Ring 14	11	Ring 24	17	Ring 34	20	Ring 44	14
Ring 5	17	Ring 15	7	Ring 25	15	Ring 35	21	Ring 45	20
Ring 6	24	Ring 16	10	Ring 26	19	Ring 36	10	Ring 46	15
Ring 7	20	Ring 17	5	Ring 27	7	Ring 37	3	Ring 47	11
Ring 8	23	Ring 18	7	Ring 28	17	Ring 38	10	Ring 48	15
Ring 9	19	Ring 19	4	Ring 29	19	Ring 39	14	Ring 49	6
Ring 10	23	Ring 20	7	Ring 30	12	Ring 40	11	Ring 50	10

Measurements in mm

Sequence graph recording sheet

Y1



Sequence Table

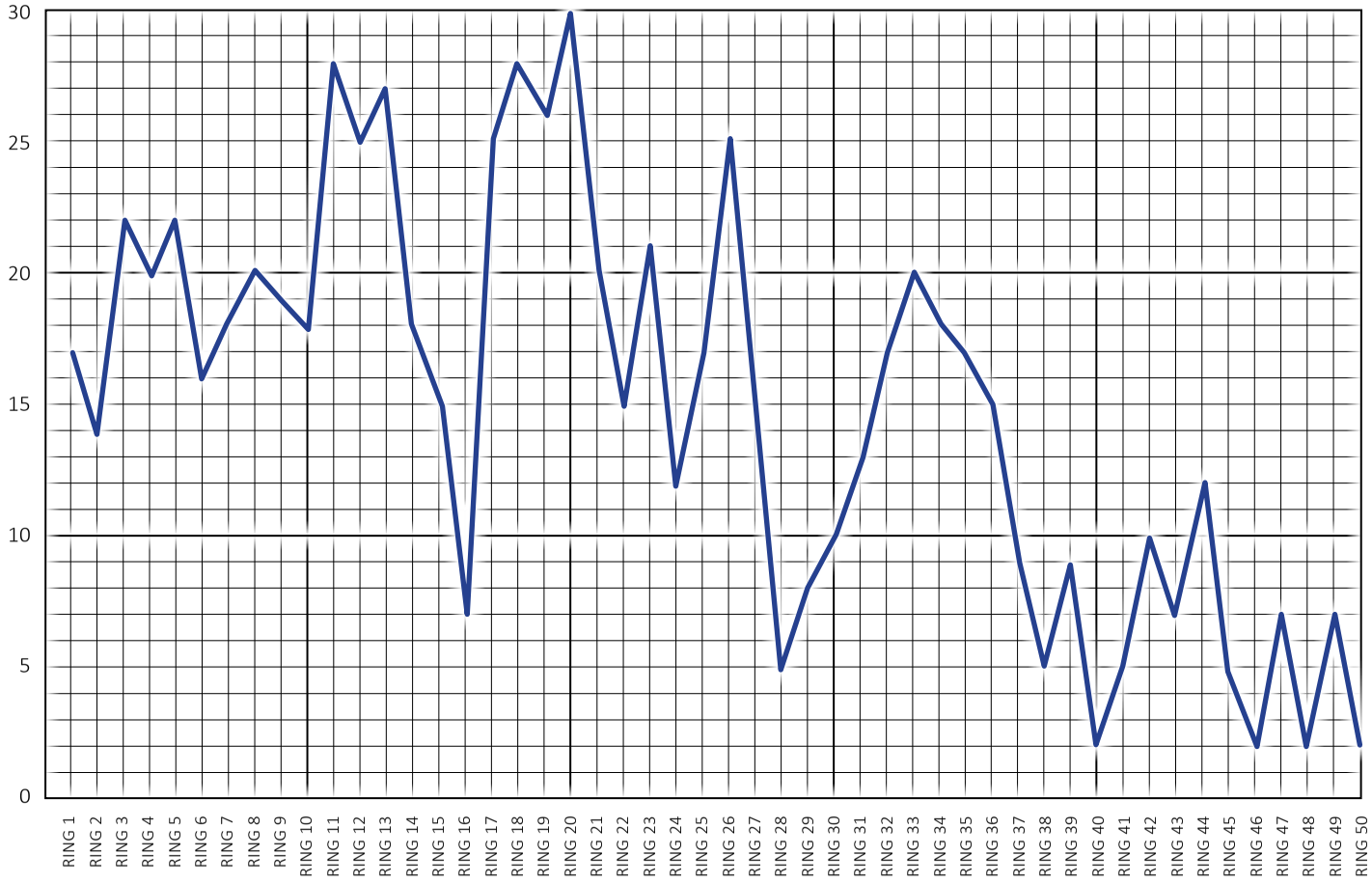
AD 1333 - AD 1382

Ring 1	21	Ring 11	20	Ring 21	6	Ring 31	15	Ring 41	18
Ring 2	10	Ring 12	15	Ring 22	13	Ring 32	20	Ring 42	20
Ring 3	3	Ring 13	11	Ring 23	20	Ring 33	22	Ring 43	19
Ring 4	10	Ring 14	15	Ring 24	13	Ring 34	13	Ring 44	18
Ring 5	14	Ring 15	6	Ring 25	15	Ring 35	17	Ring 45	28
Ring 6	11	Ring 16	10	Ring 26	17	Ring 36	14	Ring 46	25
Ring 7	15	Ring 17	8	Ring 27	20	Ring 37	22	Ring 47	27
Ring 8	12	Ring 18	7	Ring 28	15	Ring 38	20	Ring 48	18
Ring 9	18	Ring 19	2	Ring 29	3	Ring 39	22	Ring 49	15
Ring 10	14	Ring 20	10	Ring 30	10	Ring 40	16	Ring 50	7

Measurements in mm

Sequence graph recording sheet

T1



Sequence Table

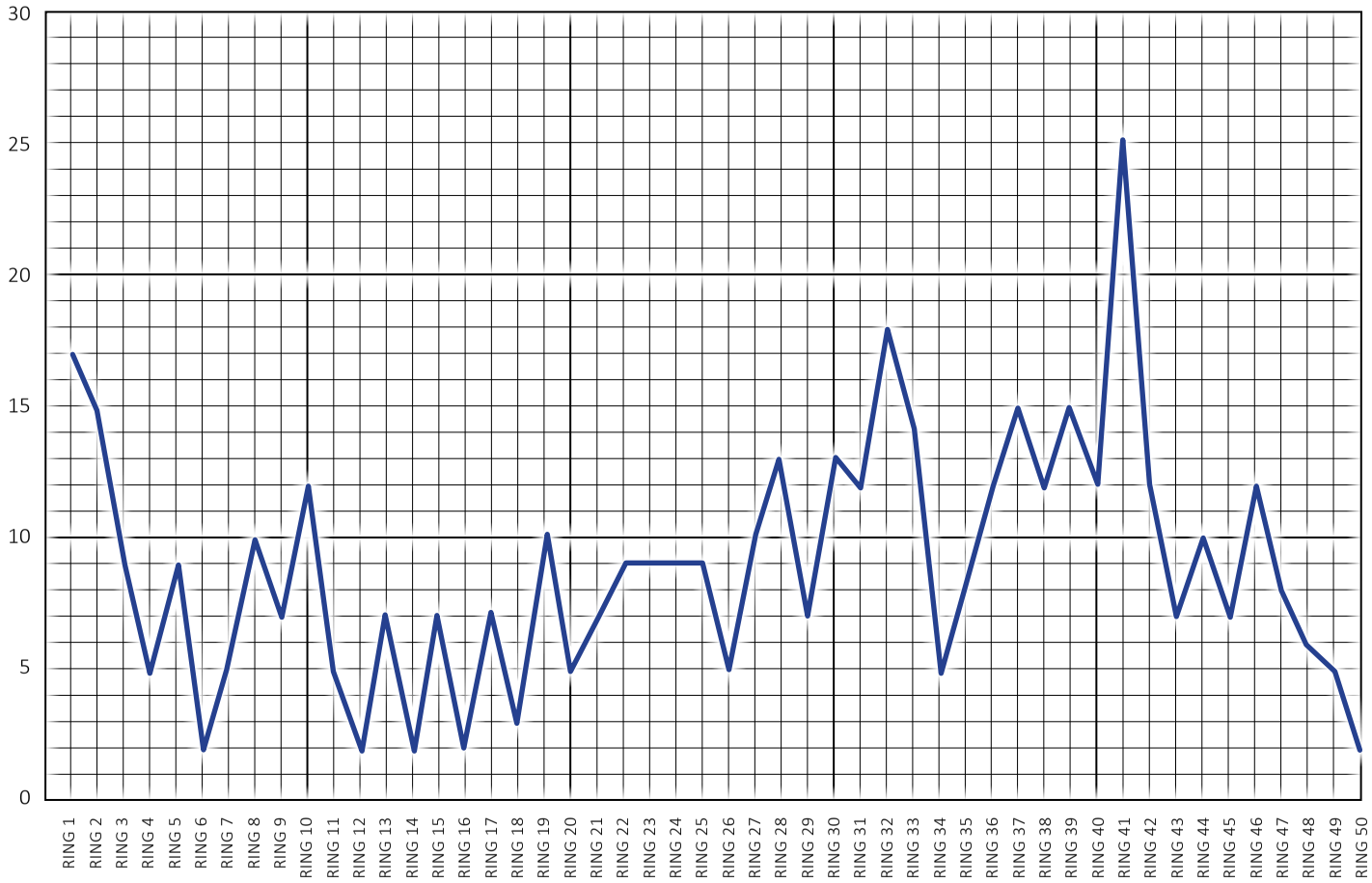
AD 1367 - AD 1416

Ring 1	17	Ring 11	28	Ring 21	20	Ring 31	13	Ring 41	5
Ring 2	14	Ring 12	25	Ring 22	15	Ring 32	17	Ring 42	10
Ring 3	22	Ring 13	27	Ring 23	21	Ring 33	20	Ring 43	7
Ring 4	20	Ring 14	18	Ring 24	12	Ring 34	18	Ring 44	12
Ring 5	22	Ring 15	15	Ring 25	17	Ring 35	17	Ring 45	5
Ring 6	16	Ring 16	7	Ring 26	25	Ring 36	15	Ring 46	2
Ring 7	18	Ring 17	25	Ring 27	15	Ring 37	9	Ring 47	7
Ring 8	20	Ring 18	28	Ring 28	5	Ring 38	5	Ring 48	2
Ring 9	19	Ring 19	26	Ring 29	8	Ring 39	9	Ring 49	7
Ring 10	18	Ring 20	30	Ring 30	10	Ring 40	2	Ring 50	2

Measurements in mm

Sequence graph recording sheet

R3



Sequence Table

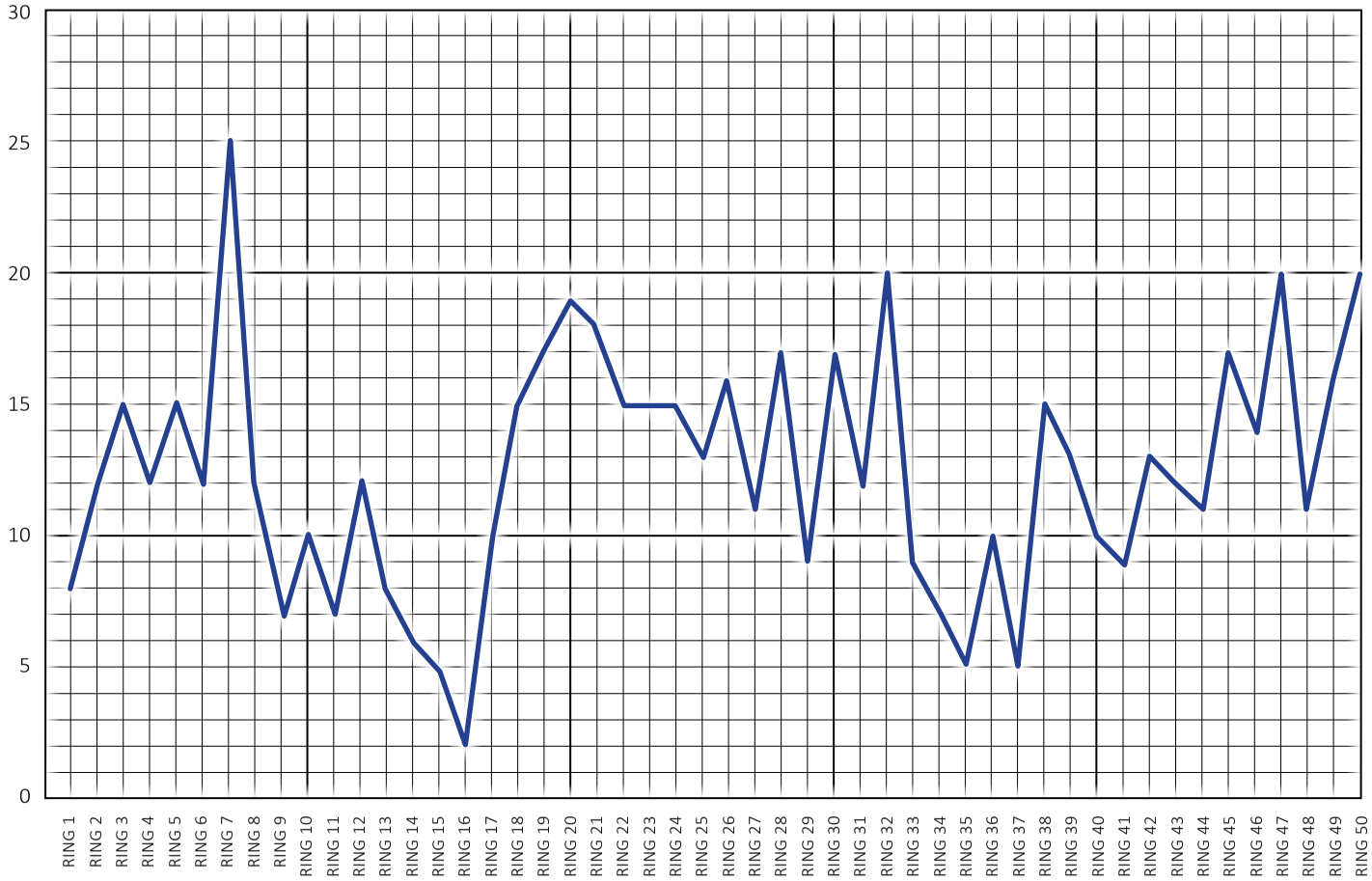
AD 1401 - AD 1450

Ring 1	17	Ring 11	5	Ring 21	7	Ring 31	12	Ring 41	25
Ring 2	15	Ring 12	2	Ring 22	9	Ring 32	18	Ring 42	12
Ring 3	9	Ring 13	7	Ring 23	9	Ring 33	14	Ring 43	7
Ring 4	5	Ring 14	2	Ring 24	9	Ring 34	5	Ring 44	10
Ring 5	9	Ring 15	7	Ring 25	9	Ring 35	8	Ring 45	7
Ring 6	2	Ring 16	2	Ring 26	5	Ring 36	12	Ring 46	12
Ring 7	5	Ring 17	7	Ring 27	10	Ring 37	15	Ring 47	8
Ring 8	10	Ring 18	3	Ring 28	13	Ring 38	12	Ring 48	6
Ring 9	7	Ring 19	10	Ring 29	7	Ring 39	15	Ring 49	5
Ring 10	12	Ring 20	5	Ring 30	13	Ring 40	12	Ring 50	2

Measurements in mm

Sequence graph recording sheet

E2



Sequence Table

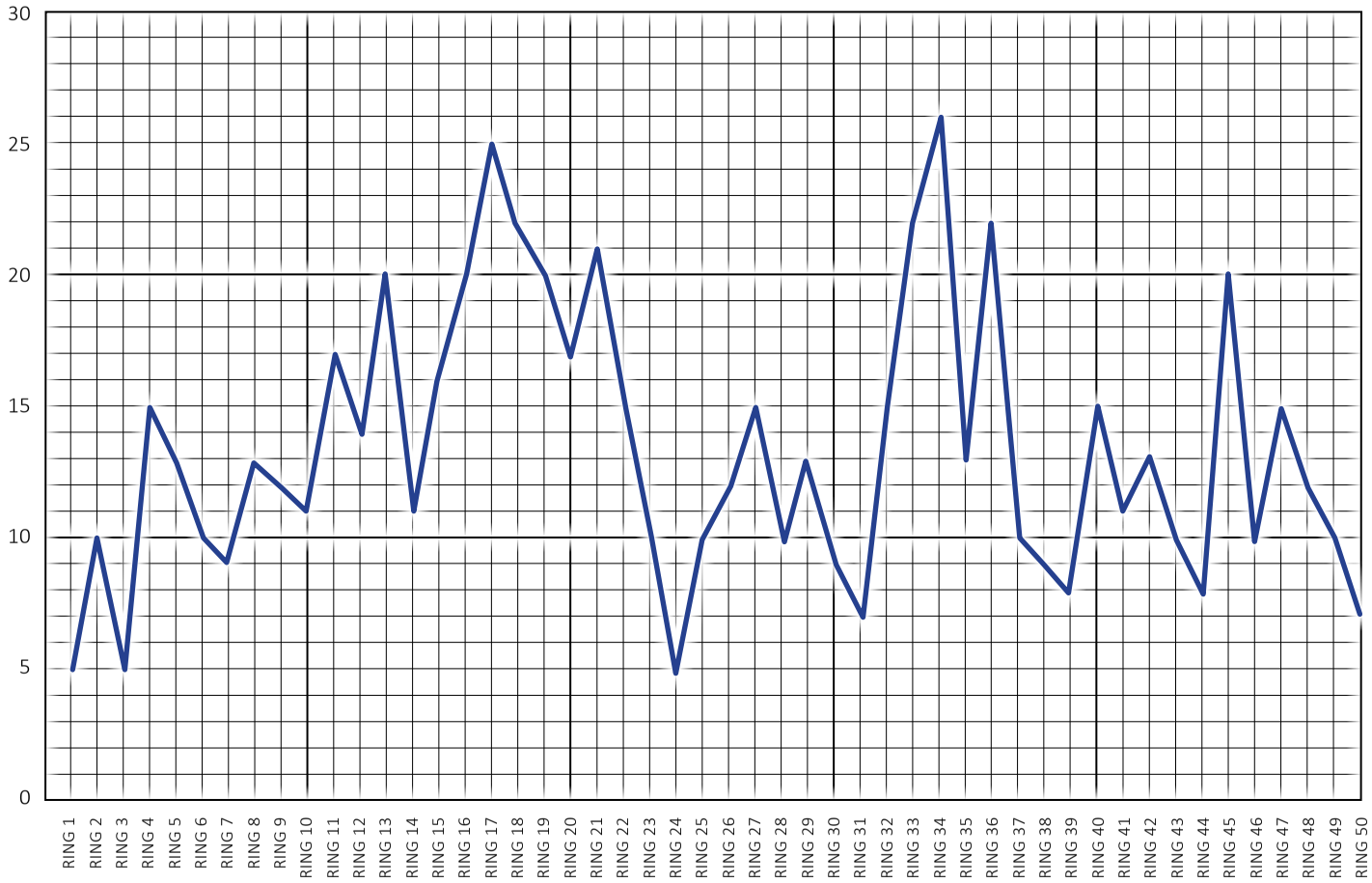
AD 1435 - AD 1484

Ring 1	8	Ring 11	7	Ring 21	18	Ring 31	12	Ring 41	9
Ring 2	12	Ring 12	12	Ring 22	15	Ring 32	20	Ring 42	13
Ring 3	15	Ring 13	8	Ring 23	15	Ring 33	9	Ring 43	12
Ring 4	12	Ring 14	6	Ring 24	15	Ring 34	7	Ring 44	11
Ring 5	15	Ring 15	5	Ring 25	13	Ring 35	5	Ring 45	17
Ring 6	12	Ring 16	2	Ring 26	16	Ring 36	10	Ring 46	14
Ring 7	25	Ring 17	10	Ring 27	11	Ring 37	5	Ring 47	20
Ring 8	12	Ring 18	15	Ring 28	17	Ring 38	15	Ring 48	11
Ring 9	7	Ring 19	17	Ring 29	9	Ring 39	13	Ring 49	16
Ring 10	10	Ring 20	19	Ring 30	17	Ring 40	10	Ring 50	20

Measurements in mm

Sequence graph recording sheet

E3



Sequence Table

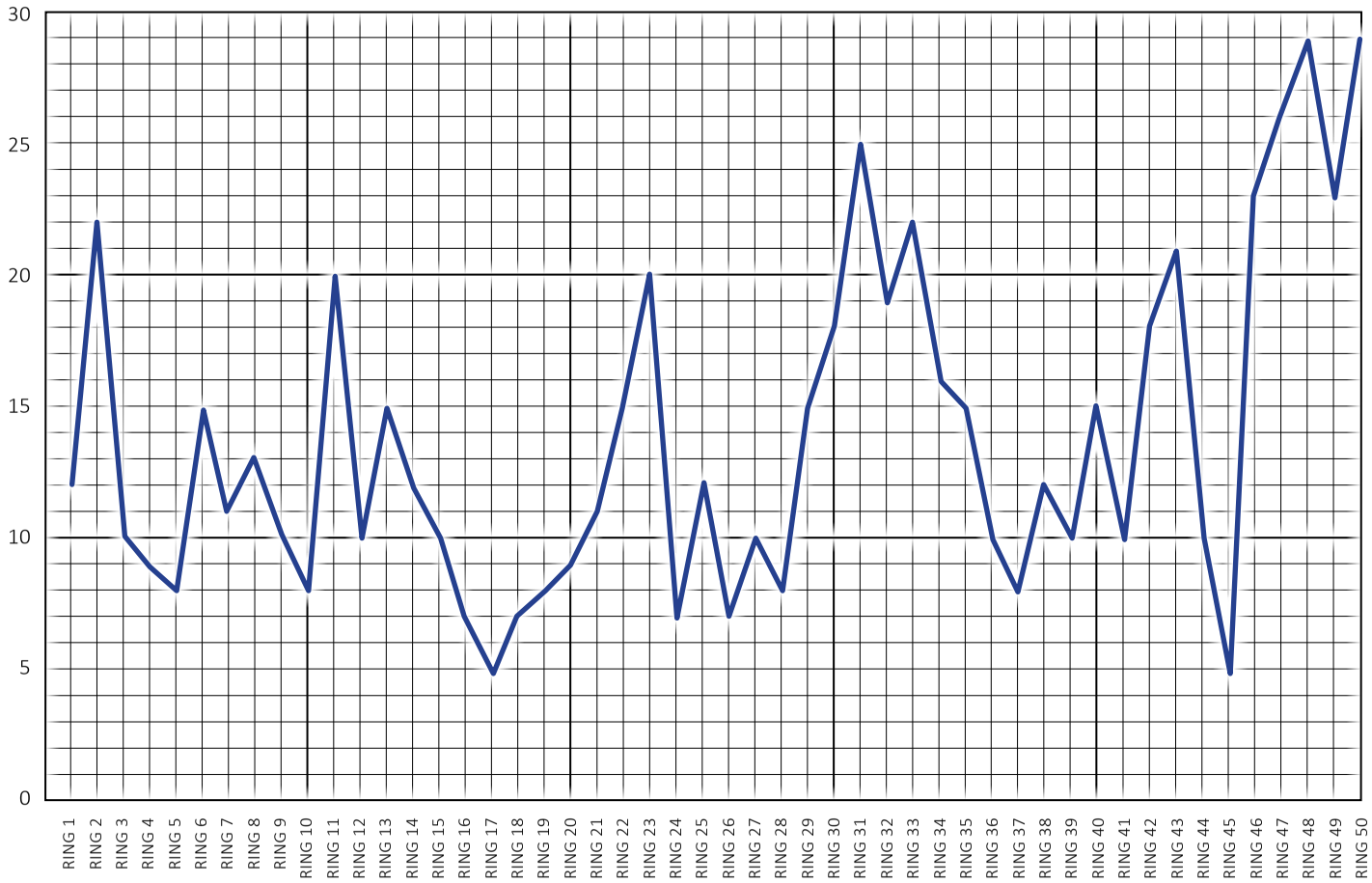
AD 1469 - AD 1518

Ring 1	5	Ring 11	17	Ring 21	21	Ring 31	7	Ring 41	11
Ring 2	10	Ring 12	14	Ring 22	15	Ring 32	15	Ring 42	13
Ring 3	5	Ring 13	20	Ring 23	10	Ring 33	22	Ring 43	10
Ring 4	15	Ring 14	11	Ring 24	5	Ring 34	26	Ring 44	8
Ring 5	13	Ring 15	16	Ring 25	10	Ring 35	12	Ring 45	20
Ring 6	10	Ring 16	20	Ring 26	12	Ring 36	22	Ring 46	10
Ring 7	9	Ring 17	25	Ring 27	15	Ring 37	10	Ring 47	15
Ring 8	13	Ring 18	22	Ring 28	10	Ring 38	9	Ring 48	12
Ring 9	12	Ring 19	20	Ring 29	13	Ring 39	8	Ring 49	10
Ring 10	11	Ring 20	17	Ring 30	9	Ring 40	15	Ring 50	7

Measurements in mm

Sequence graph recording sheet

R4



Sequence Table

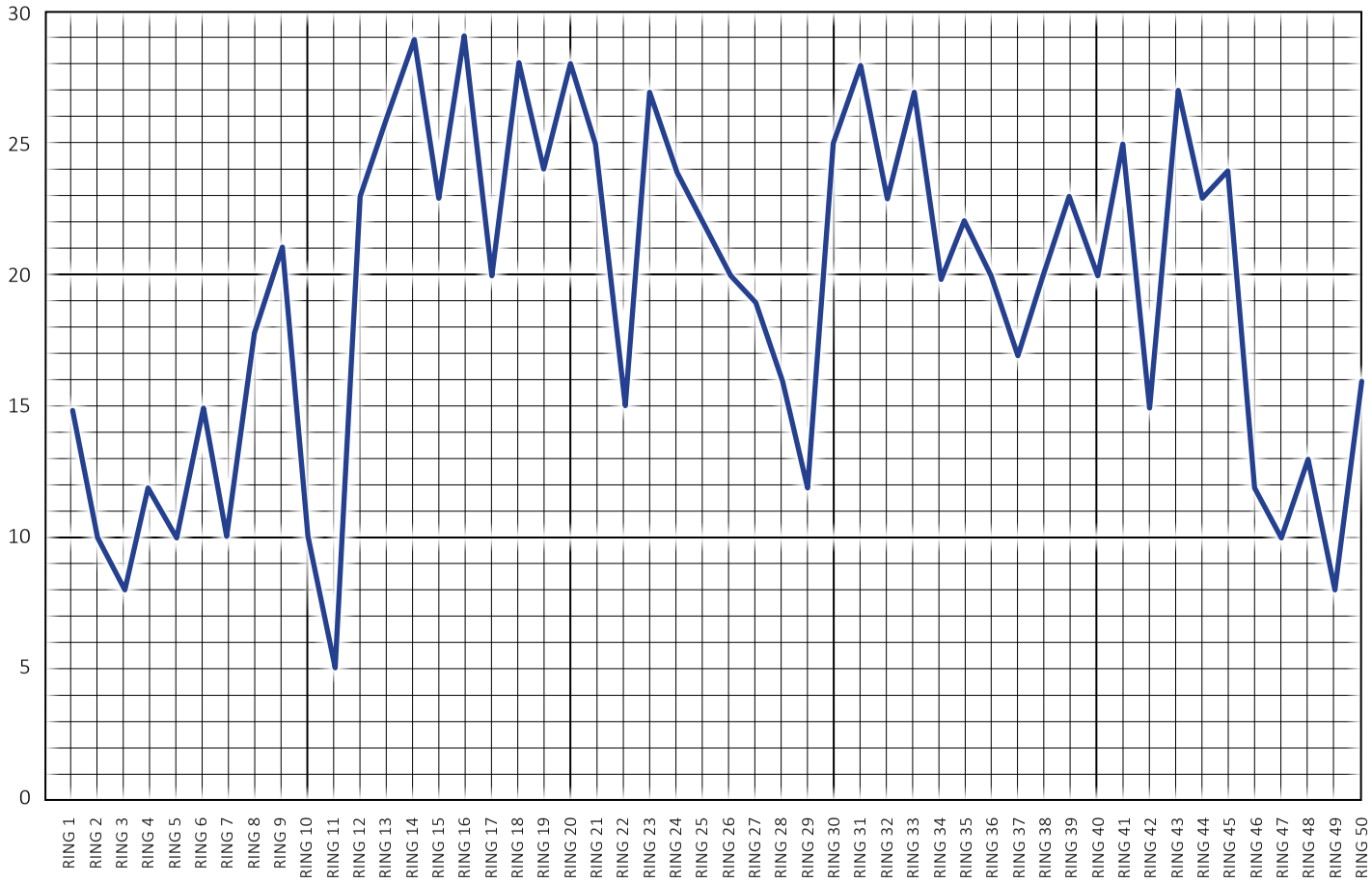
AD 1503 - AD 1552

Ring 1	12	Ring 11	20	Ring 21	11	Ring 31	25	Ring 41	10
Ring 2	22	Ring 12	10	Ring 22	15	Ring 32	19	Ring 42	18
Ring 3	10	Ring 13	15	Ring 23	20	Ring 33	22	Ring 43	21
Ring 4	9	Ring 14	12	Ring 24	7	Ring 34	16	Ring 44	10
Ring 5	8	Ring 15	10	Ring 25	12	Ring 35	15	Ring 45	5
Ring 6	15	Ring 16	7	Ring 26	7	Ring 36	10	Ring 46	23
Ring 7	11	Ring 17	5	Ring 27	10	Ring 37	8	Ring 47	26
Ring 8	13	Ring 18	7	Ring 28	8	Ring 38	12	Ring 48	29
Ring 9	10	Ring 19	8	Ring 29	15	Ring 39	10	Ring 49	23
Ring 10	8	Ring 20	9	Ring 30	18	Ring 40	15	Ring 50	29

Measurements in mm

Sequence graph recording sheet

I1



Sequence Table

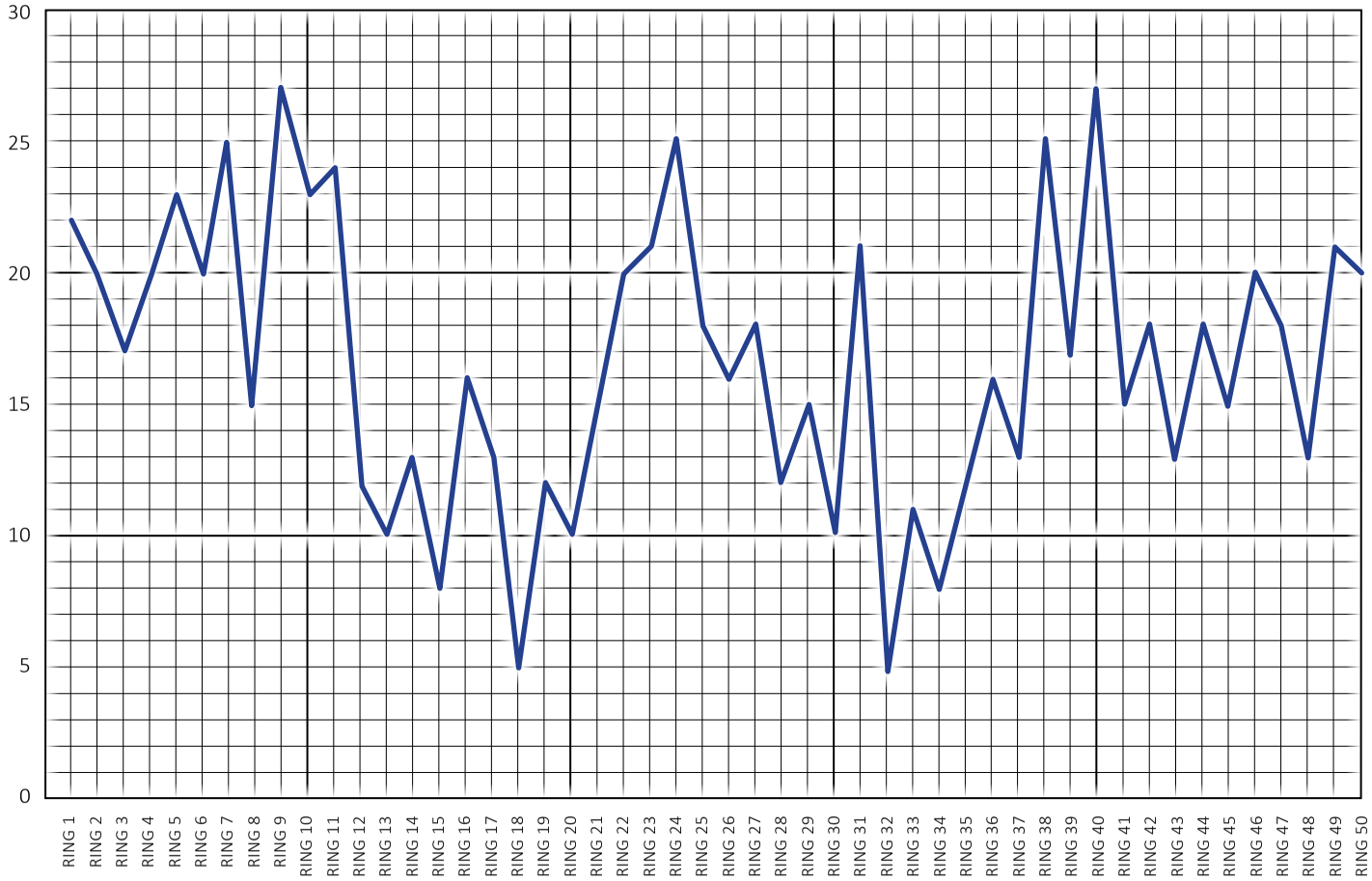
AD 1537 - AD 1586

Ring 1	15	Ring 11	5	Ring 21	25	Ring 31	28	Ring 41	25
Ring 2	10	Ring 12	23	Ring 22	15	Ring 32	23	Ring 42	15
Ring 3	8	Ring 13	26	Ring 23	27	Ring 33	27	Ring 43	27
Ring 4	12	Ring 14	29	Ring 24	24	Ring 34	20	Ring 44	23
Ring 5	10	Ring 15	23	Ring 25	22	Ring 35	22	Ring 45	24
Ring 6	15	Ring 16	29	Ring 26	20	Ring 36	20	Ring 46	12
Ring 7	10	Ring 17	20	Ring 27	19	Ring 37	17	Ring 47	10
Ring 8	18	Ring 18	28	Ring 28	16	Ring 38	20	Ring 48	13
Ring 9	21	Ring 19	24	Ring 29	12	Ring 39	23	Ring 49	8
Ring 10	10	Ring 20	28	Ring 30	25	Ring 40	20	Ring 50	16

Measurements in mm

Sequence graph recording sheet

N3



Sequence Table

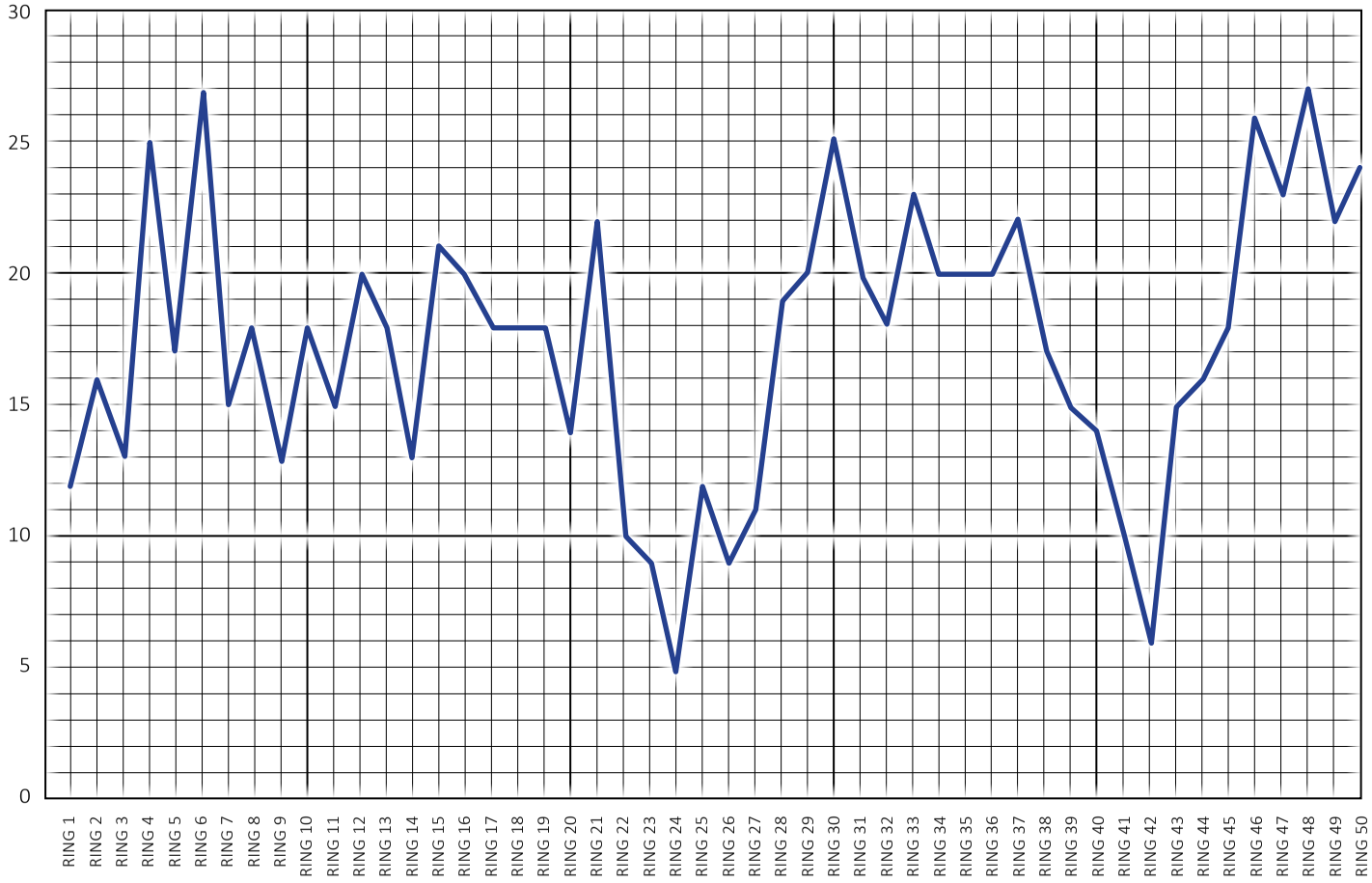
AD 1571 - AD 1620

Ring 1	22	Ring 11	24	Ring 21	15	Ring 31	21	Ring 41	15
Ring 2	20	Ring 12	12	Ring 22	20	Ring 32	5	Ring 42	18
Ring 3	17	Ring 13	10	Ring 23	21	Ring 33	11	Ring 43	13
Ring 4	20	Ring 14	13	Ring 24	25	Ring 34	8	Ring 44	18
Ring 5	23	Ring 15	8	Ring 25	18	Ring 35	12	Ring 45	15
Ring 6	20	Ring 16	16	Ring 26	16	Ring 36	16	Ring 46	20
Ring 7	25	Ring 17	13	Ring 27	18	Ring 37	13	Ring 47	18
Ring 8	15	Ring 18	5	Ring 28	12	Ring 38	25	Ring 48	13
Ring 9	27	Ring 19	12	Ring 29	15	Ring 39	17	Ring 49	21
Ring 10	23	Ring 20	10	Ring 30	10	Ring 40	27	Ring 50	20

Measurements in mm

Sequence graph recording sheet

G2



Sequence Table

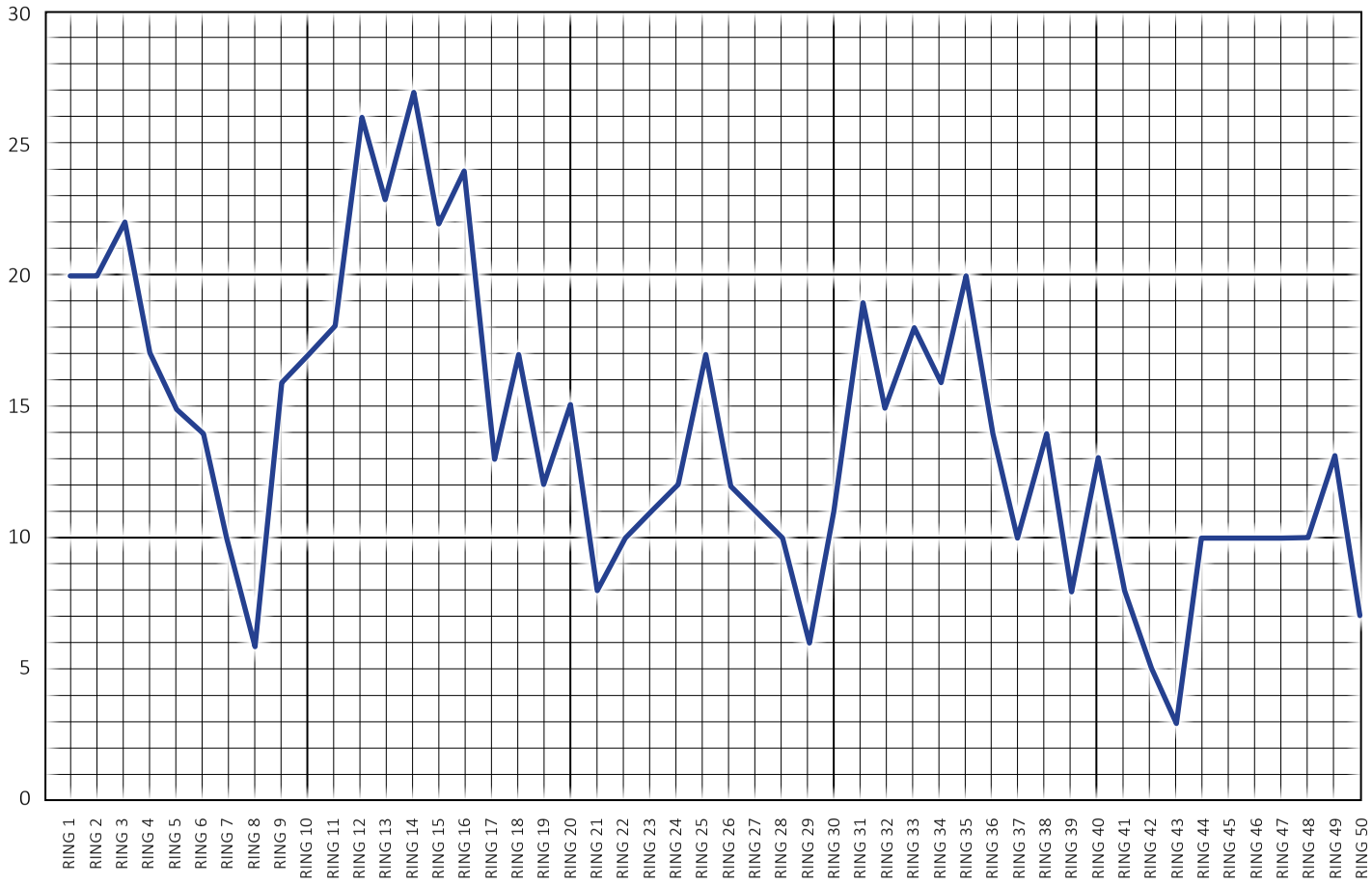
AD 1605 - AD 1654

Ring 1	12	Ring 11	15	Ring 21	22	Ring 31	20	Ring 41	10
Ring 2	16	Ring 12	20	Ring 22	10	Ring 32	18	Ring 42	6
Ring 3	13	Ring 13	18	Ring 23	9	Ring 33	23	Ring 43	15
Ring 4	25	Ring 14	13	Ring 24	5	Ring 34	20	Ring 44	16
Ring 5	17	Ring 15	21	Ring 25	12	Ring 35	20	Ring 45	18
Ring 6	27	Ring 16	20	Ring 26	9	Ring 36	20	Ring 46	26
Ring 7	15	Ring 17	18	Ring 27	11	Ring 37	22	Ring 47	23
Ring 8	18	Ring 18	18	Ring 28	19	Ring 38	17	Ring 48	27
Ring 9	13	Ring 19	18	Ring 29	20	Ring 39	15	Ring 49	22
Ring 10	18	Ring 20	14	Ring 30	25	Ring 40	14	Ring 50	24

Measurements in mm

Sequence graph recording sheet

D3



Sequence Table

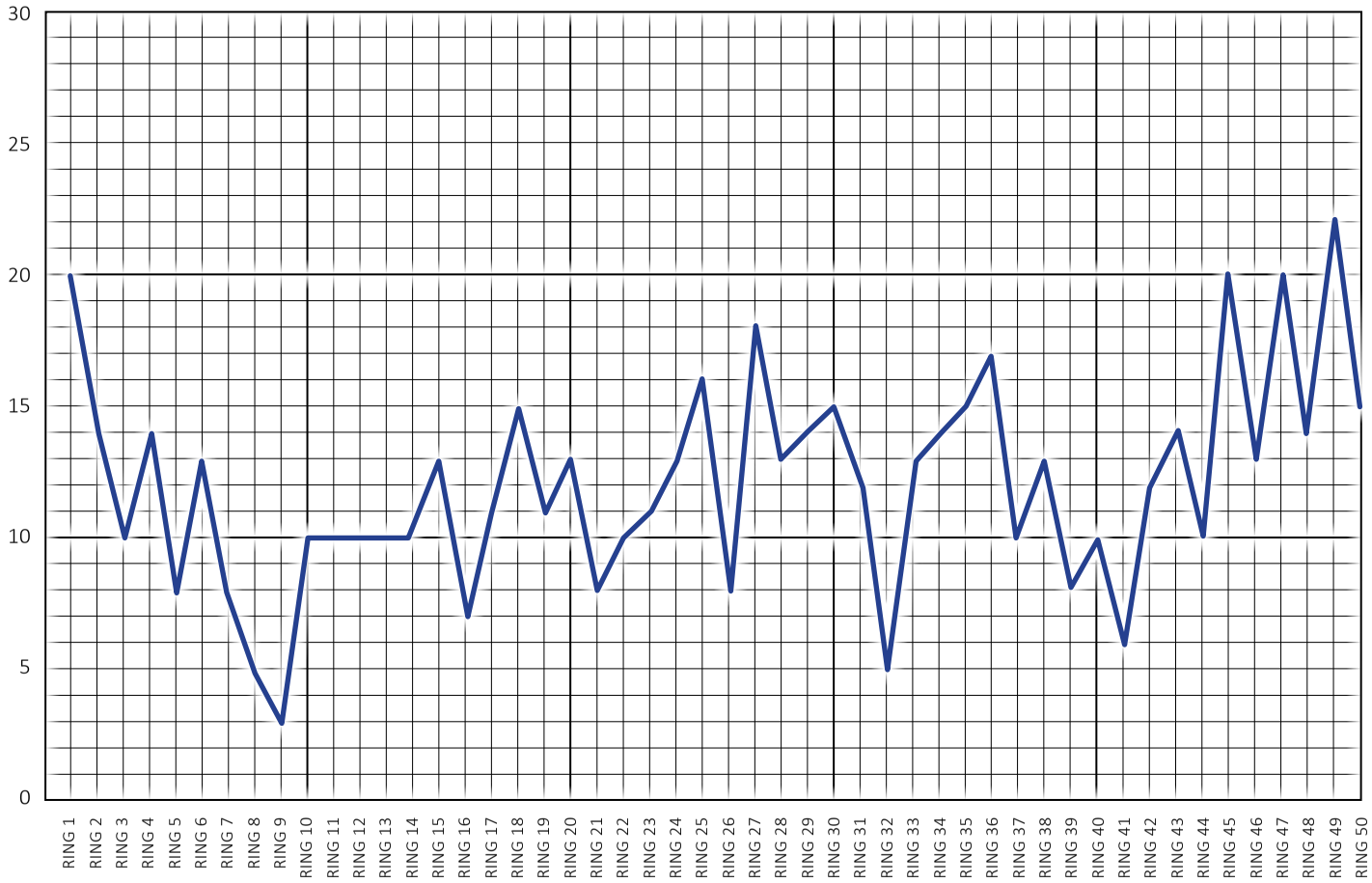
AD 1639 - AD 1688

Ring 1	20	Ring 11	18	Ring 21	8	Ring 31	19	Ring 41	8
Ring 2	20	Ring 12	26	Ring 22	10	Ring 32	15	Ring 42	5
Ring 3	22	Ring 13	23	Ring 23	11	Ring 33	18	Ring 43	3
Ring 4	17	Ring 14	27	Ring 24	12	Ring 34	16	Ring 44	10
Ring 5	15	Ring 15	22	Ring 25	17	Ring 35	20	Ring 45	10
Ring 6	14	Ring 16	24	Ring 26	12	Ring 36	14	Ring 46	10
Ring 7	10	Ring 17	13	Ring 27	11	Ring 37	10	Ring 47	10
Ring 8	6	Ring 18	17	Ring 28	10	Ring 38	14	Ring 48	10
Ring 9	15	Ring 19	12	Ring 29	6	Ring 39	8	Ring 49	13
Ring 10	16	Ring 20	15	Ring 30	11	Ring 40	13	Ring 50	7

Measurements in mm

Sequence graph recording sheet

A1



Sequence Table

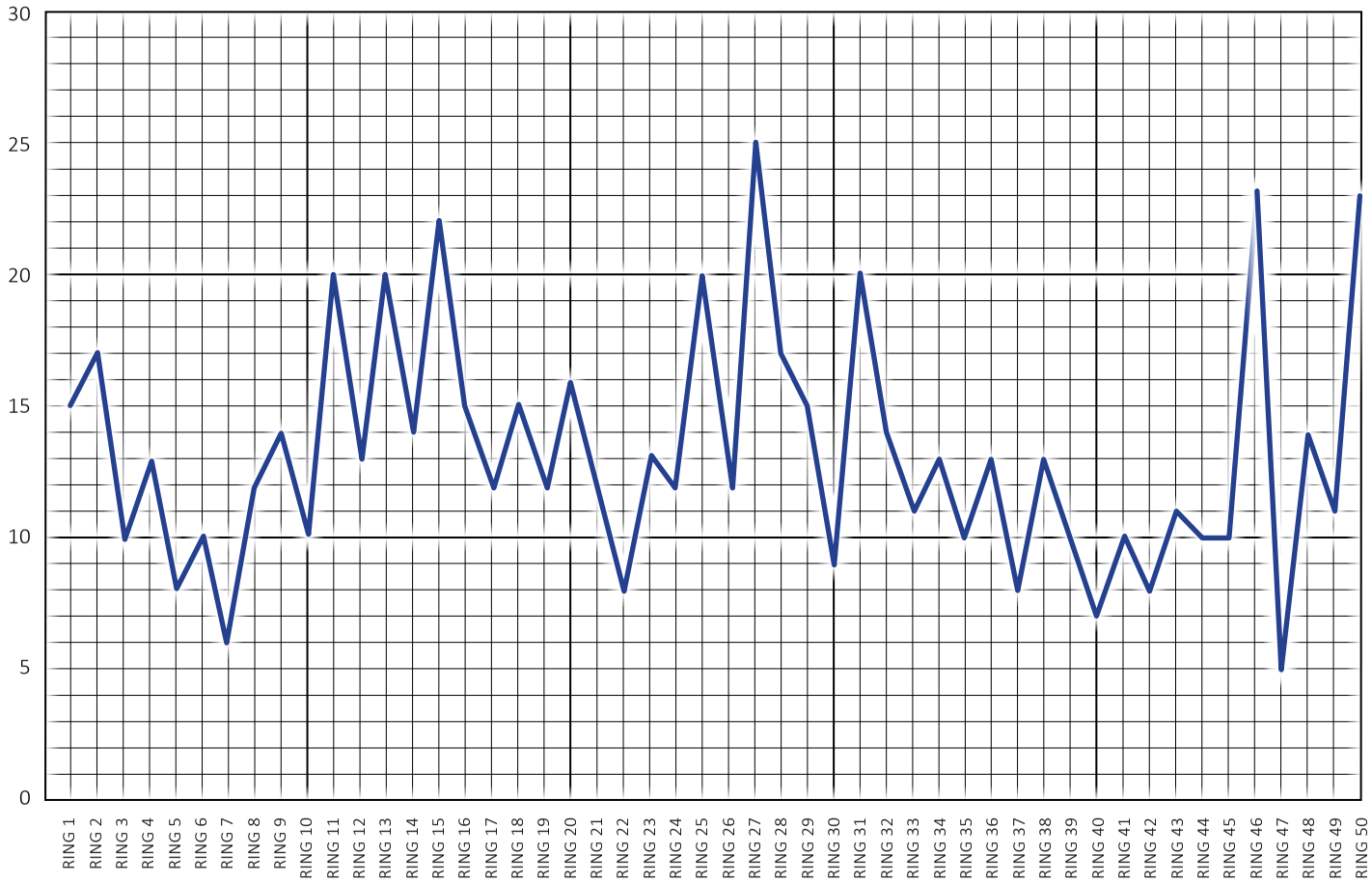
AD 1673 - AD 1722

Ring 1	20	Ring 11	10	Ring 21	8	Ring 31	12	Ring 41	6
Ring 2	14	Ring 12	10	Ring 22	10	Ring 32	5	Ring 42	12
Ring 3	10	Ring 13	10	Ring 23	11	Ring 33	13	Ring 43	14
Ring 4	14	Ring 14	10	Ring 24	13	Ring 34	14	Ring 44	10
Ring 5	8	Ring 15	13	Ring 25	16	Ring 35	15	Ring 45	20
Ring 6	13	Ring 16	7	Ring 26	8	Ring 36	17	Ring 46	13
Ring 7	8	Ring 17	11	Ring 27	18	Ring 37	10	Ring 47	20
Ring 8	5	Ring 18	15	Ring 28	13	Ring 38	13	Ring 48	14
Ring 9	3	Ring 19	11	Ring 29	14	Ring 39	8	Ring 49	22
Ring 10	10	Ring 20	13	Ring 30	15	Ring 40	10	Ring 50	15

Measurements in mm

Sequence graph recording sheet

T2



Sequence Table

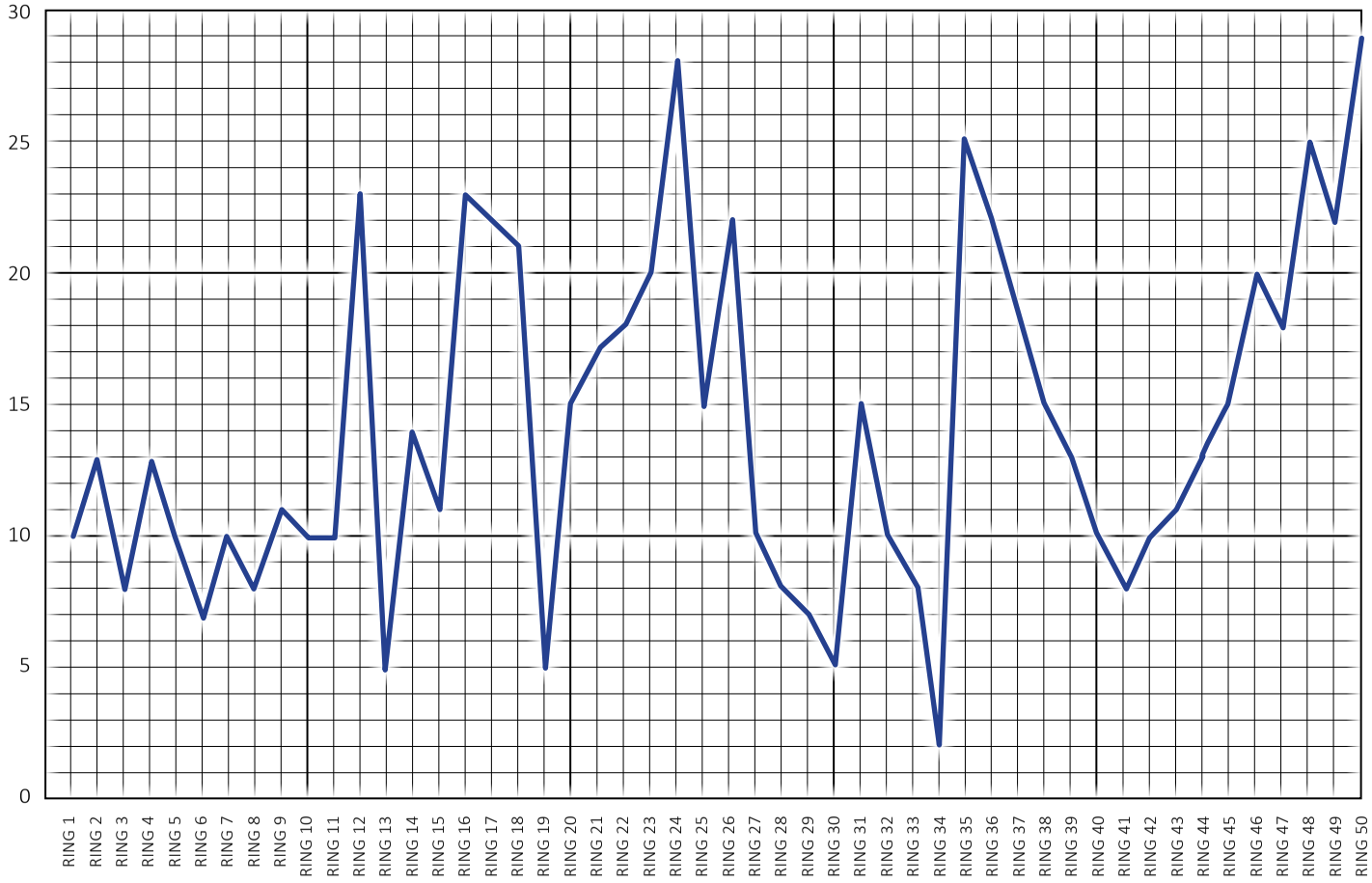
AD 1707 - AD 1756

Ring 1	15	Ring 11	20	Ring 21	12	Ring 31	20	Ring 41	10
Ring 2	17	Ring 12	13	Ring 22	8	Ring 32	14	Ring 42	8
Ring 3	10	Ring 13	20	Ring 23	13	Ring 33	11	Ring 43	11
Ring 4	13	Ring 14	14	Ring 24	12	Ring 34	13	Ring 44	10
Ring 5	8	Ring 15	22	Ring 25	20	Ring 35	10	Ring 45	10
Ring 6	10	Ring 16	15	Ring 26	12	Ring 36	13	Ring 46	23
Ring 7	6	Ring 17	12	Ring 27	25	Ring 37	8	Ring 47	5
Ring 8	12	Ring 18	15	Ring 28	17	Ring 38	13	Ring 48	14
Ring 9	14	Ring 19	12	Ring 29	15	Ring 39	10	Ring 49	11
Ring 10	10	Ring 20	16	Ring 30	9	Ring 40	7	Ring 50	23

Measurements in mm

Sequence graph recording sheet

I2



Sequence Table

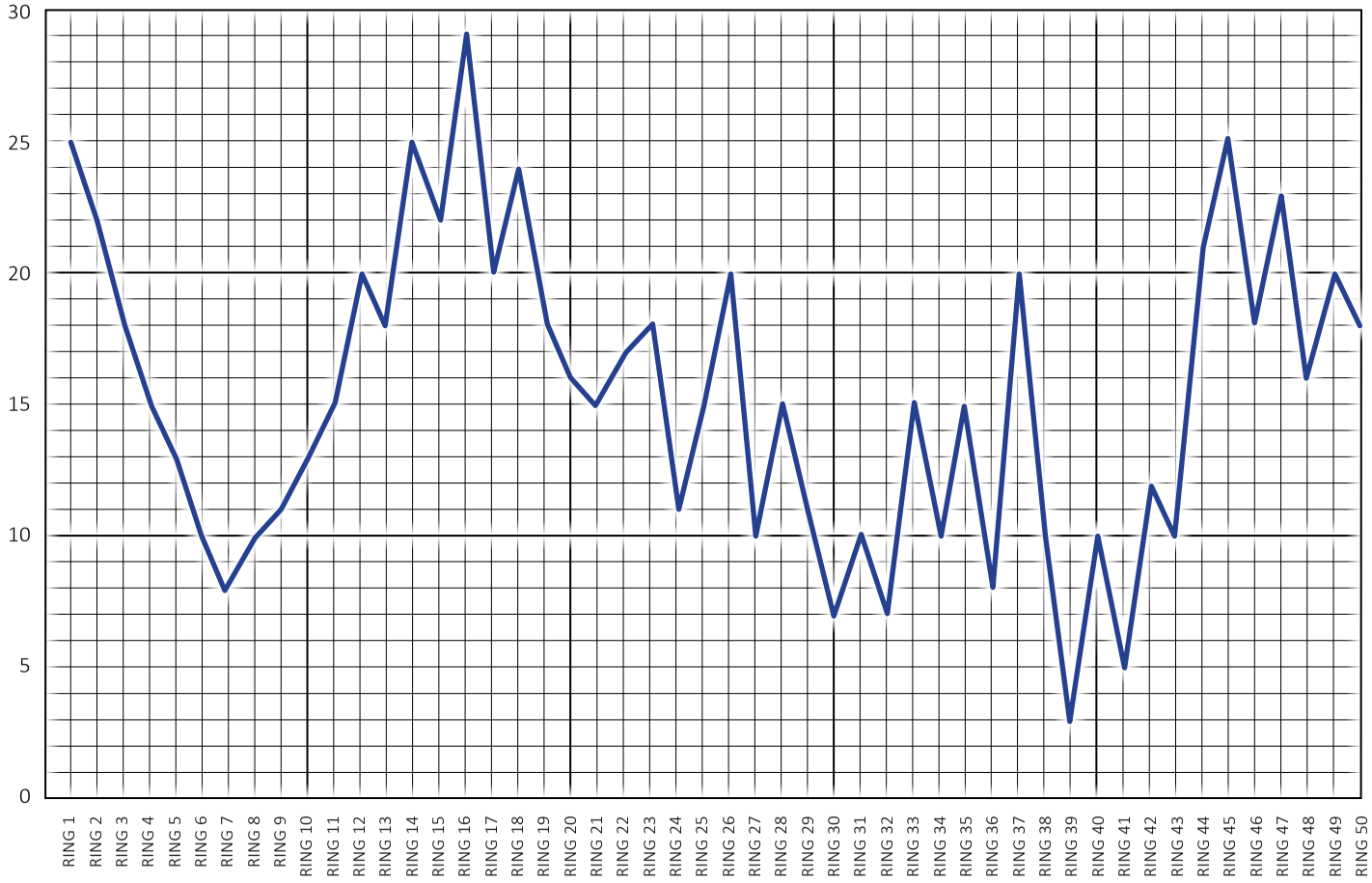
AD 1741 - AD 1790

Ring 1	10	Ring 11	10	Ring 21	17	Ring 31	15	Ring 41	8
Ring 2	13	Ring 12	23	Ring 22	18	Ring 32	10	Ring 42	10
Ring 3	8	Ring 13	5	Ring 23	20	Ring 33	8	Ring 43	11
Ring 4	13	Ring 14	14	Ring 24	28	Ring 34	2	Ring 44	13
Ring 5	10	Ring 15	11	Ring 25	15	Ring 35	25	Ring 45	15
Ring 6	7	Ring 16	23	Ring 26	22	Ring 36	22	Ring 46	20
Ring 7	10	Ring 17	22	Ring 27	10	Ring 37	18	Ring 47	18
Ring 8	8	Ring 18	21	Ring 28	8	Ring 38	15	Ring 48	25
Ring 9	11	Ring 19	5	Ring 29	7	Ring 39	13	Ring 49	22
Ring 10	10	Ring 20	15	Ring 30	5	Ring 40	10	Ring 50	29

Measurements in mm

Sequence graph recording sheet

N4



Sequence Table

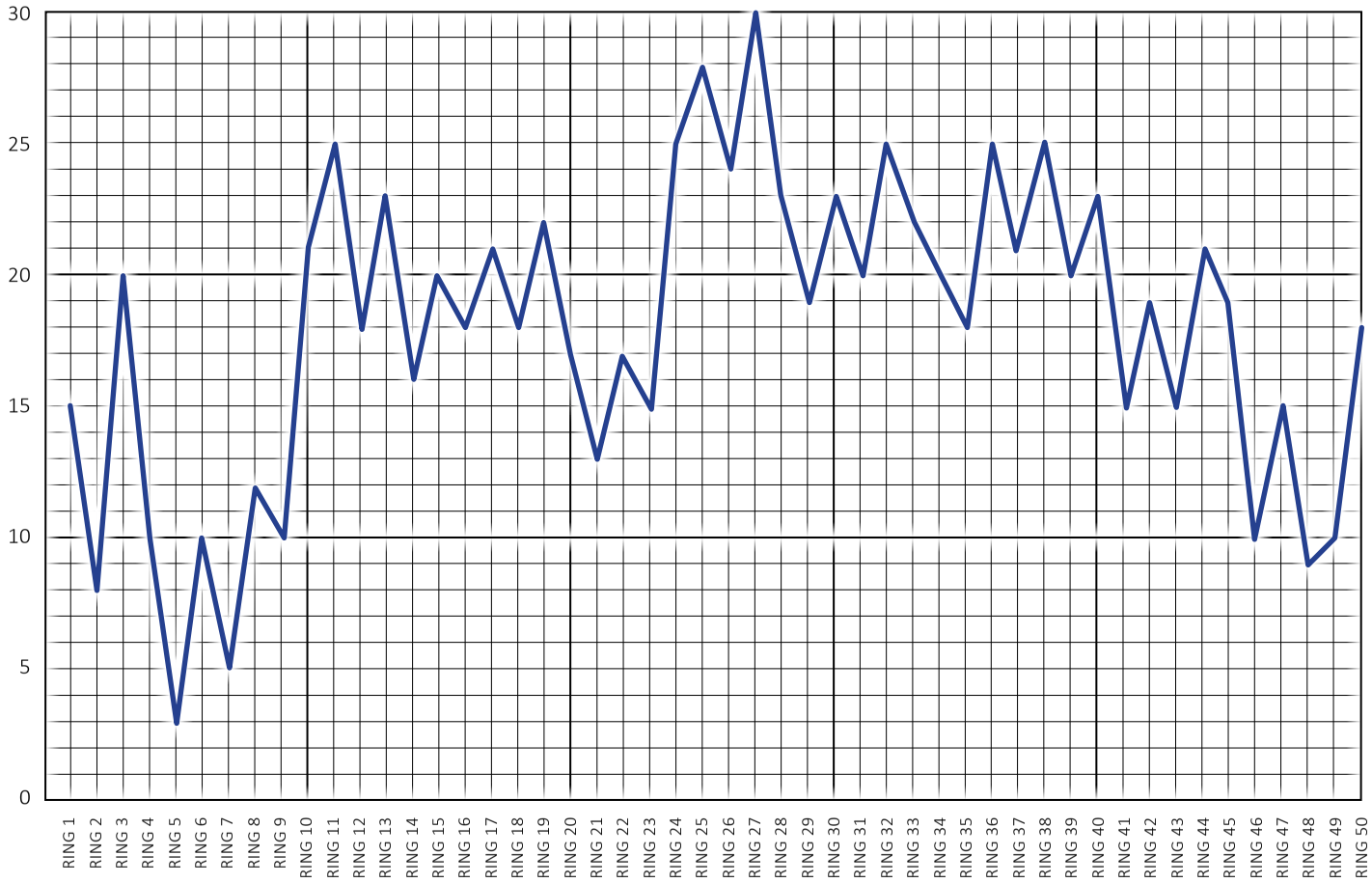
AD 1775 - AD 1824

Ring 1	25	Ring 11	15	Ring 21	15	Ring 31	10	Ring 41	5
Ring 2	22	Ring 12	20	Ring 22	17	Ring 32	7	Ring 42	12
Ring 3	18	Ring 13	18	Ring 23	18	Ring 33	15	Ring 43	10
Ring 4	15	Ring 14	25	Ring 24	11	Ring 34	10	Ring 44	21
Ring 5	13	Ring 15	22	Ring 25	15	Ring 35	15	Ring 45	25
Ring 6	10	Ring 16	29	Ring 26	20	Ring 36	8	Ring 46	18
Ring 7	8	Ring 17	20	Ring 27	10	Ring 37	20	Ring 47	23
Ring 8	10	Ring 18	24	Ring 28	15	Ring 38	10	Ring 48	16
Ring 9	11	Ring 19	18	Ring 29	11	Ring 39	3	Ring 49	20
Ring 10	13	Ring 20	16	Ring 30	7	Ring 40	10	Ring 50	18

Measurements in mm

Sequence graph recording sheet

G3



Sequence Table

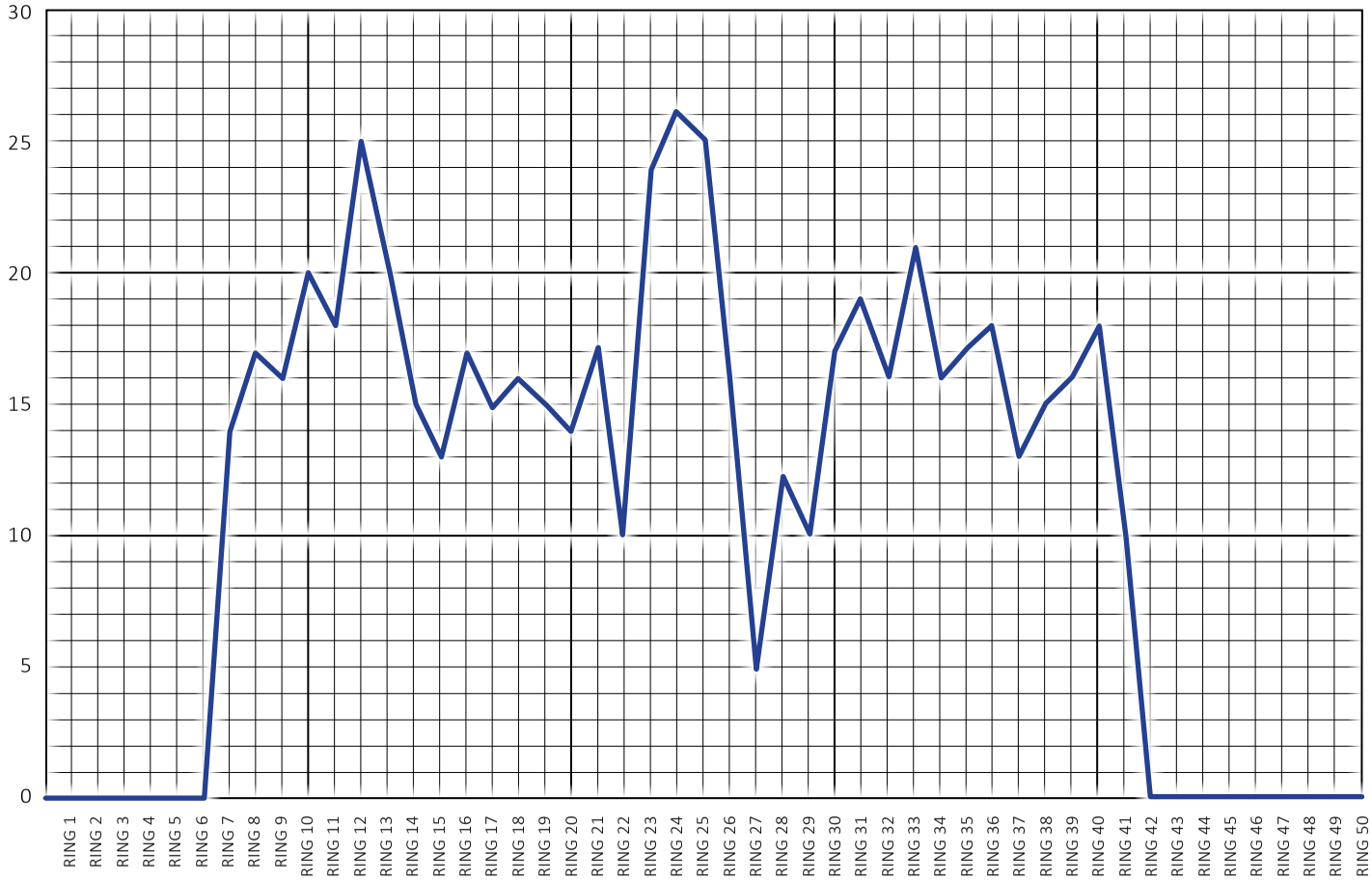
AD 1809 - AD 1858

Ring 1	15	Ring 11	25	Ring 21	13	Ring 31	20	Ring 41	15
Ring 2	8	Ring 12	18	Ring 22	17	Ring 32	25	Ring 42	19
Ring 3	20	Ring 13	23	Ring 23	15	Ring 33	22	Ring 43	15
Ring 4	10	Ring 14	16	Ring 24	25	Ring 34	20	Ring 44	21
Ring 5	3	Ring 15	20	Ring 25	28	Ring 35	18	Ring 45	19
Ring 6	10	Ring 16	18	Ring 26	24	Ring 36	25	Ring 46	10
Ring 7	5	Ring 17	21	Ring 27	30	Ring 37	21	Ring 47	15
Ring 8	12	Ring 18	18	Ring 28	23	Ring 38	25	Ring 48	9
Ring 9	10	Ring 19	22	Ring 29	19	Ring 39	20	Ring 49	10
Ring 10	21	Ring 20	17	Ring 30	23	Ring 40	23	Ring 50	18

Measurements in mm

Sequence graph recording sheet

Bridge Foundation Pile



Sequence table: matches to sequence graph C1

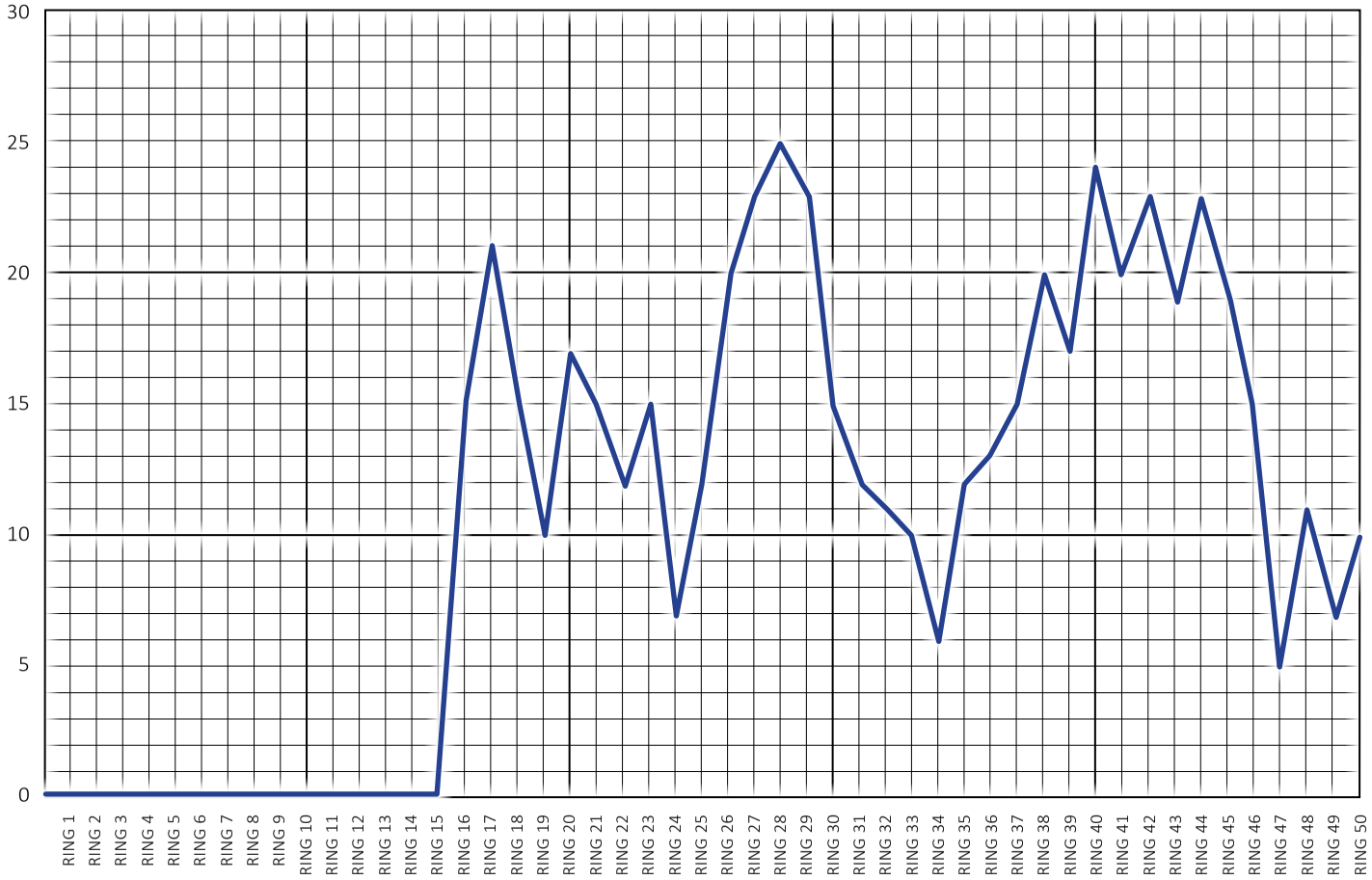
AD 1033 - AD 1070

Ring 7	14	Ring 17	15	Ring 27	5	Ring 37	13		
Ring 8	17	Ring 18	16	Ring 28	12	Ring 38	15		
Ring 9	16	Ring 19	15	Ring 29	10	Ring 39	16		
Ring 10	20	Ring 20	14	Ring 30	17	Ring 40	18		
Ring 11	18	Ring 21	17	Ring 31	19	Ring 41	10		
Ring 12	25	Ring 22	10	Ring 32	16				
Ring 13	20	Ring 23	24	Ring 33	21				
Ring 14	15	Ring 24	26	Ring 34	16				
Ring 15	13	Ring 25	25	Ring 35	17				
Ring 16	17	Ring 26	16	Ring 36	18				

Measurements in mm

Sequence graph recording sheet

Rafter



Sequence table: matches to sequence graph 04

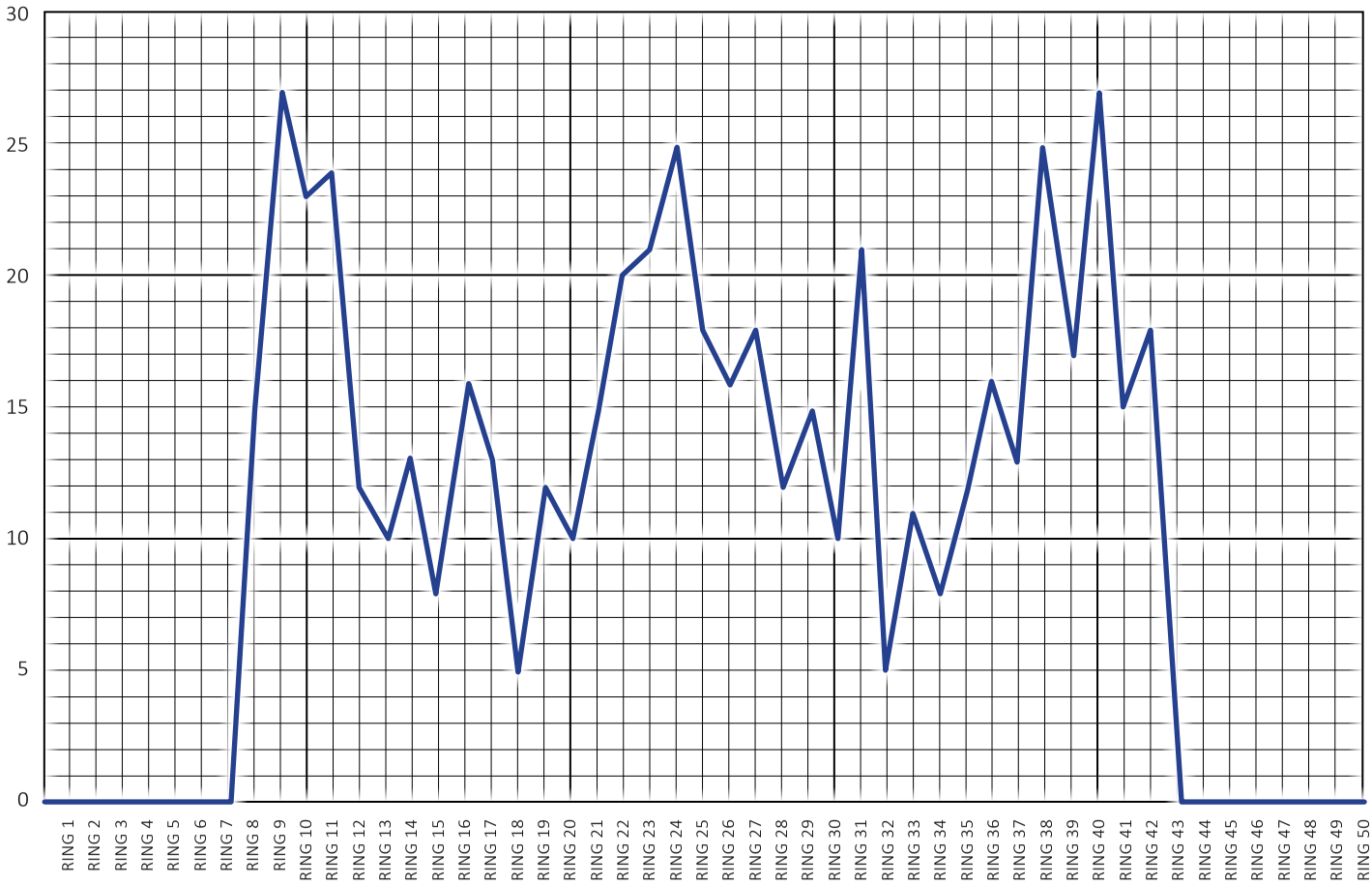
AD 1280 - AD 1314

Ring 16	15	Ring 26	20	Ring 36	13	Ring 46	15		
Ring 17	21	Ring 27	23	Ring 37	15	Ring 47	5		
Ring 18	15	Ring 28	25	Ring 38	20	Ring 48	11		
Ring 19	10	Ring 29	23	Ring 39	17	Ring 49	7		
Ring 20	17	Ring 30	15	Ring 40	24	Ring 50	10		
Ring 21	15	Ring 31	12	Ring 41	20				
Ring 22	12	Ring 32	11	Ring 42	23				
Ring 23	15	Ring 33	10	Ring 43	19				
Ring 24	7	Ring 34	6	Ring 44	23				
Ring 25	12	Ring 35	12	Ring 45	19				

Measurements in mm

Sequence graph recording sheet

Floorboard



Sequence table: matches to sequence graph N3

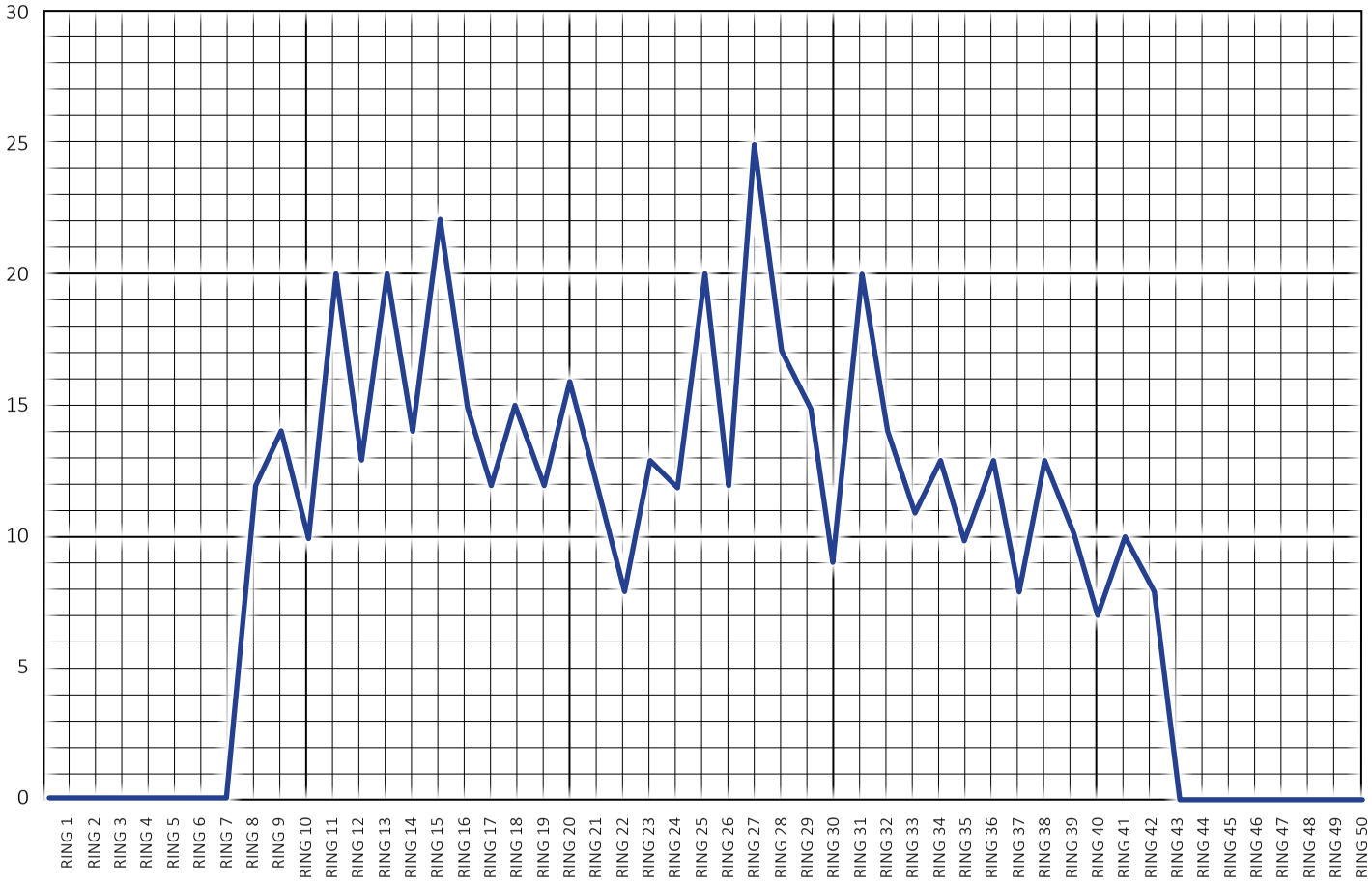
AD 1578 - AD 1612

Ring 8	15	Ring 18	5	Ring 28	12	Ring 38	25		
Ring 9	27	Ring 19	12	Ring 29	15	Ring 39	17		
Ring 10	23	Ring 20	10	Ring 30	10	Ring 40	27		
Ring 11	24	Ring 21	15	Ring 31	21	Ring 41	15		
Ring 12	12	Ring 22	20	Ring 32	5	Ring 42	18		
Ring 13	10	Ring 23	21	Ring 33	11				
Ring 14	13	Ring 24	25	Ring 34	8				
Ring 15	8	Ring 25	18	Ring 35	12				
Ring 16	16	Ring 26	16	Ring 36	16				
Ring 17	13	Ring 27	18	Ring 37	13				

Measurements in mm

Sequence graph recording sheet

Ceiling Joist



Sequence table: matches to sequence graph T2

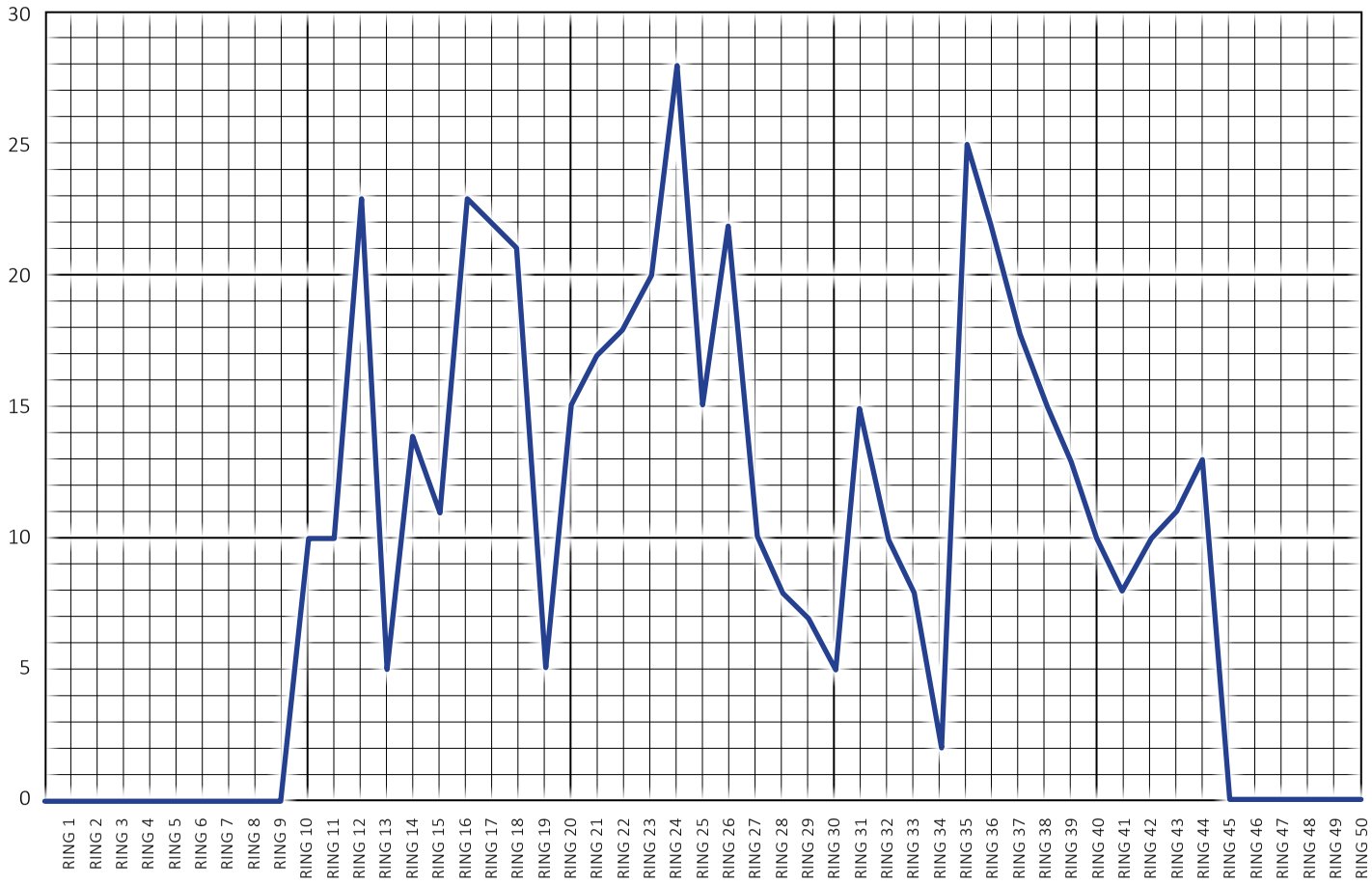
AD 1714 - AD 1748

Ring 8	12	Ring 18	15	Ring 28	17	Ring 38	13		
Ring 9	14	Ring 19	12	Ring 29	15	Ring 39	10		
Ring 10	10	Ring 20	16	Ring 30	9	Ring 40	7		
Ring 11	20	Ring 21	12	Ring 31	20	Ring 41	10		
Ring 12	13	Ring 22	8	Ring 32	14	Ring 42	8		
Ring 13	20	Ring 23	13	Ring 33	11				
Ring 14	14	Ring 24	12	Ring 34	13				
Ring 15	22	Ring 25	20	Ring 35	10				
Ring 16	15	Ring 26	12	Ring 36	13				
Ring 17	12	Ring 27	25	Ring 37	8				

Measurements in mm

Sequence graph recording sheet

Wainscott Panelling

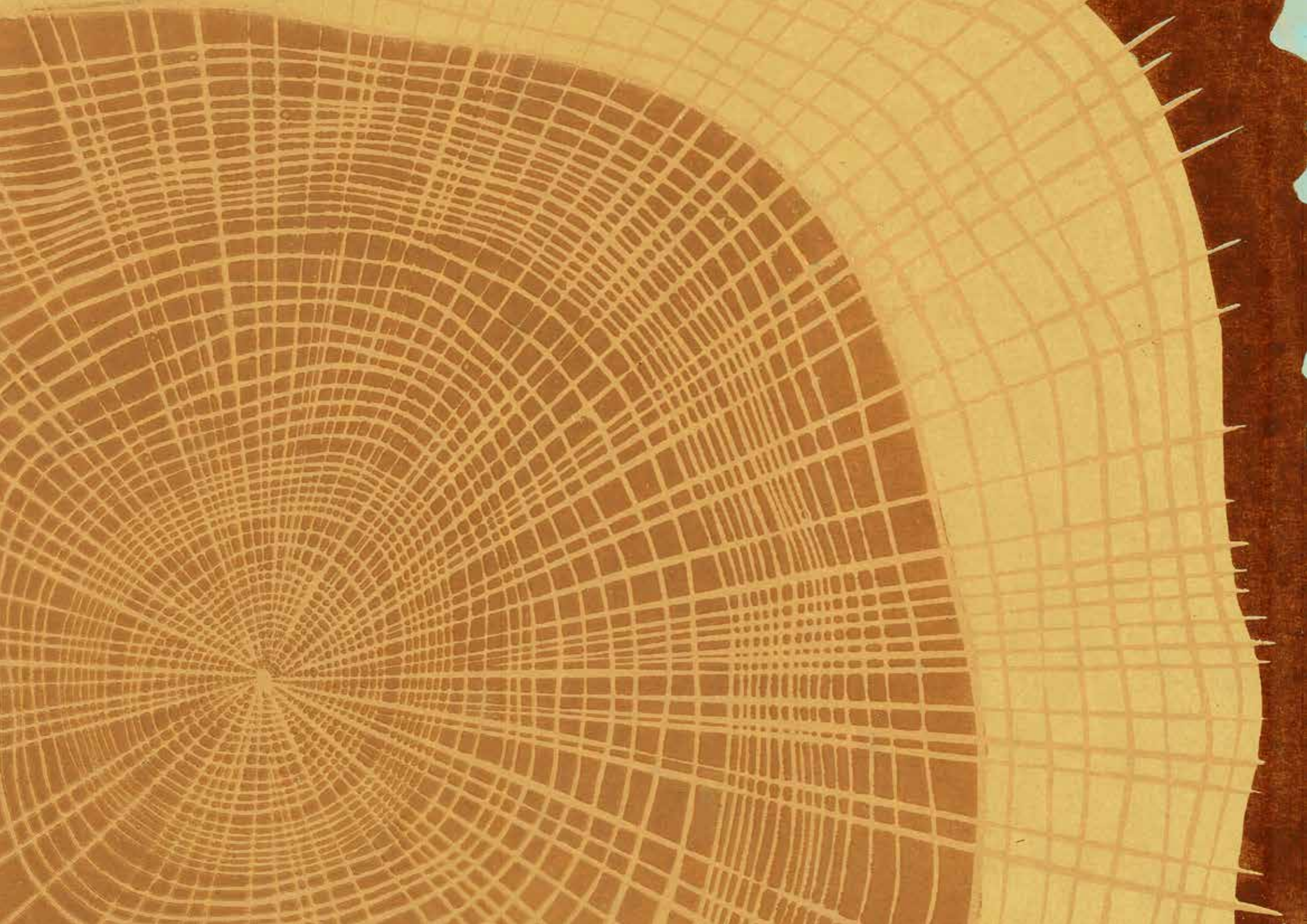


Sequence table: matches to sequence graph I2

AD 1750 - AD 1784

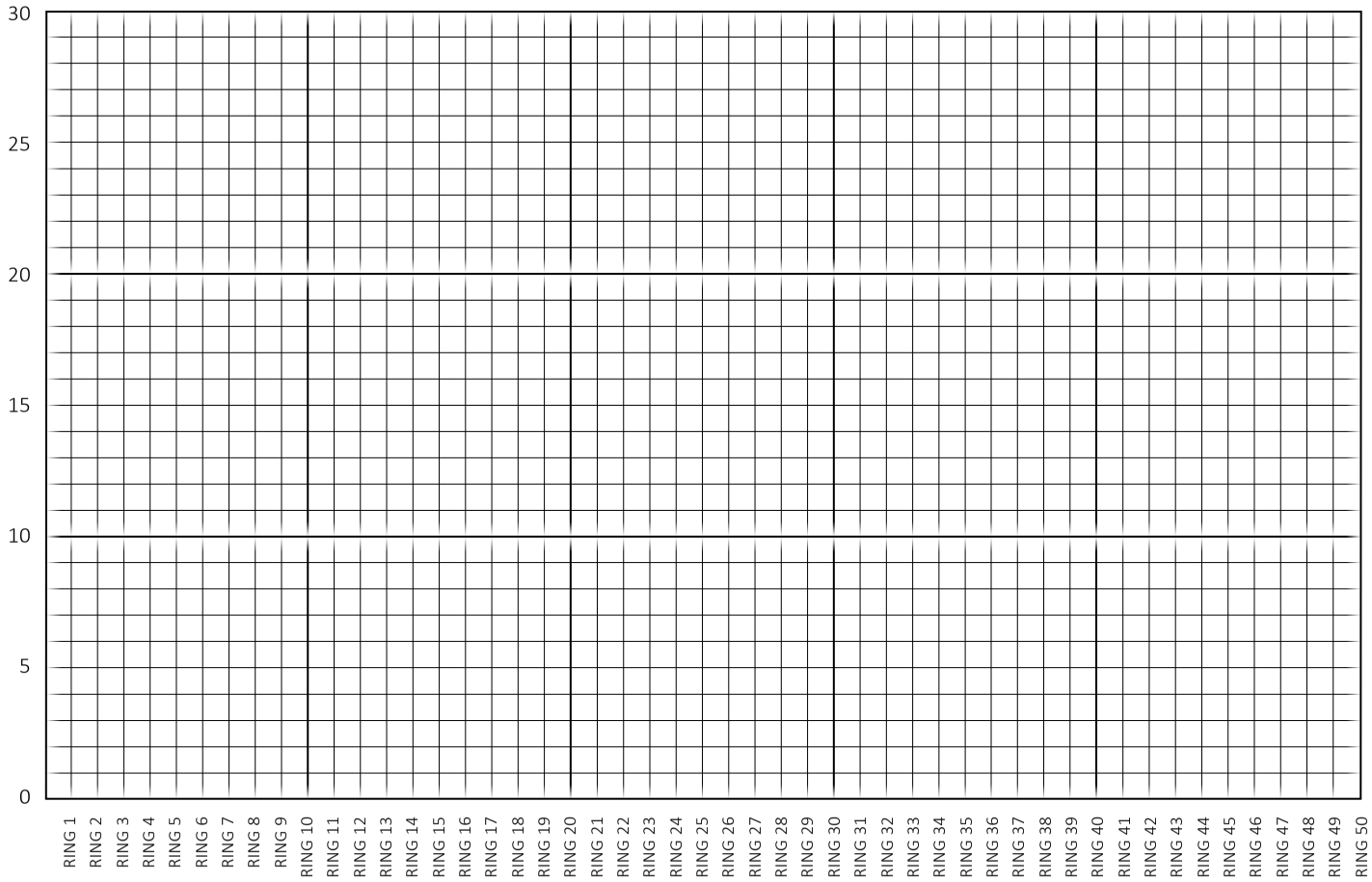
Ring 10	10	Ring 20	15	Ring 30	5	Ring 40	10		
Ring 11	10	Ring 21	17	Ring 31	15	Ring 41	8		
Ring 12	23	Ring 22	18	Ring 32	10	Ring 42	10		
Ring 13	5	Ring 23	20	Ring 33	8	Ring 43	11		
Ring 14	14	Ring 24	28	Ring 34	2	Ring 44	13		
Ring 15	11	Ring 25	15	Ring 35	25				
Ring 16	23	Ring 26	22	Ring 36	22				
Ring 17	22	Ring 27	10	Ring 37	18				
Ring 18	21	Ring 28	8	Ring 38	15				
Ring 19	5	Ring 29	7	Ring 39	13				

Measurements in mm



Sequence graph recording sheet

D1



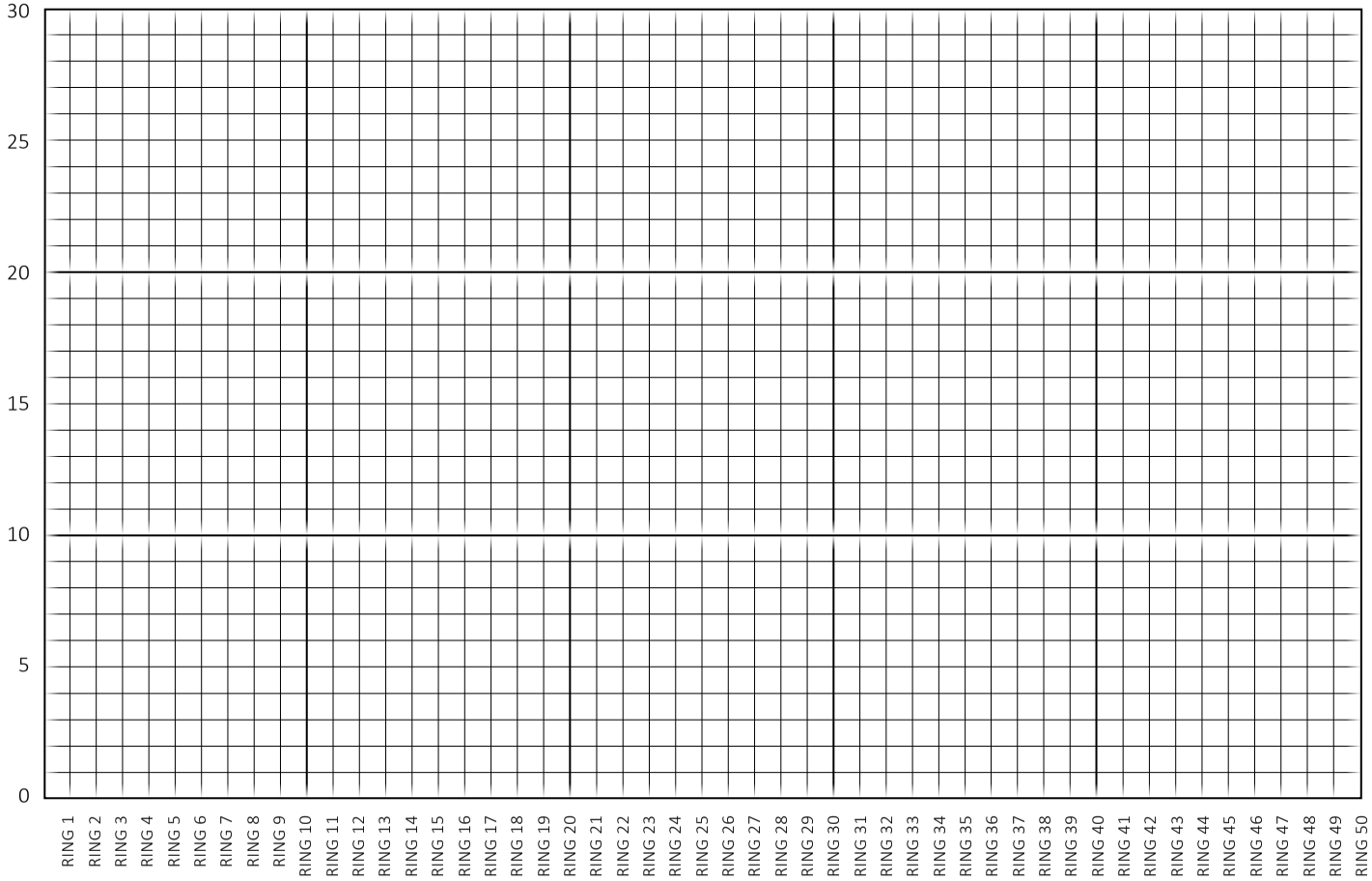
Sequence Table

Ring 1	11	Ring 11	10	Ring 21	10	Ring 31	5	Ring 41	23
Ring 2	5	Ring 12	9	Ring 22	15	Ring 32	11	Ring 42	19
Ring 3	4	Ring 13	9	Ring 23	15	Ring 33	12	Ring 43	23
Ring 4	6	Ring 14	7	Ring 24	16	Ring 34	9	Ring 44	21
Ring 5	8	Ring 15	10	Ring 25	17	Ring 35	12	Ring 45	24
Ring 6	7	Ring 16	5	Ring 26	17	Ring 36	9	Ring 46	23
Ring 7	10	Ring 17	4	Ring 27	18	Ring 37	5	Ring 47	25
Ring 8	11	Ring 18	3	Ring 28	17	Ring 38	10	Ring 48	23
Ring 9	14	Ring 19	7	Ring 29	15	Ring 39	15	Ring 49	25
Ring 10	23	Ring 20	9	Ring 30	20	Ring 40	18	Ring 50	19

Measurements in mm

Sequence graph recording sheet

E1



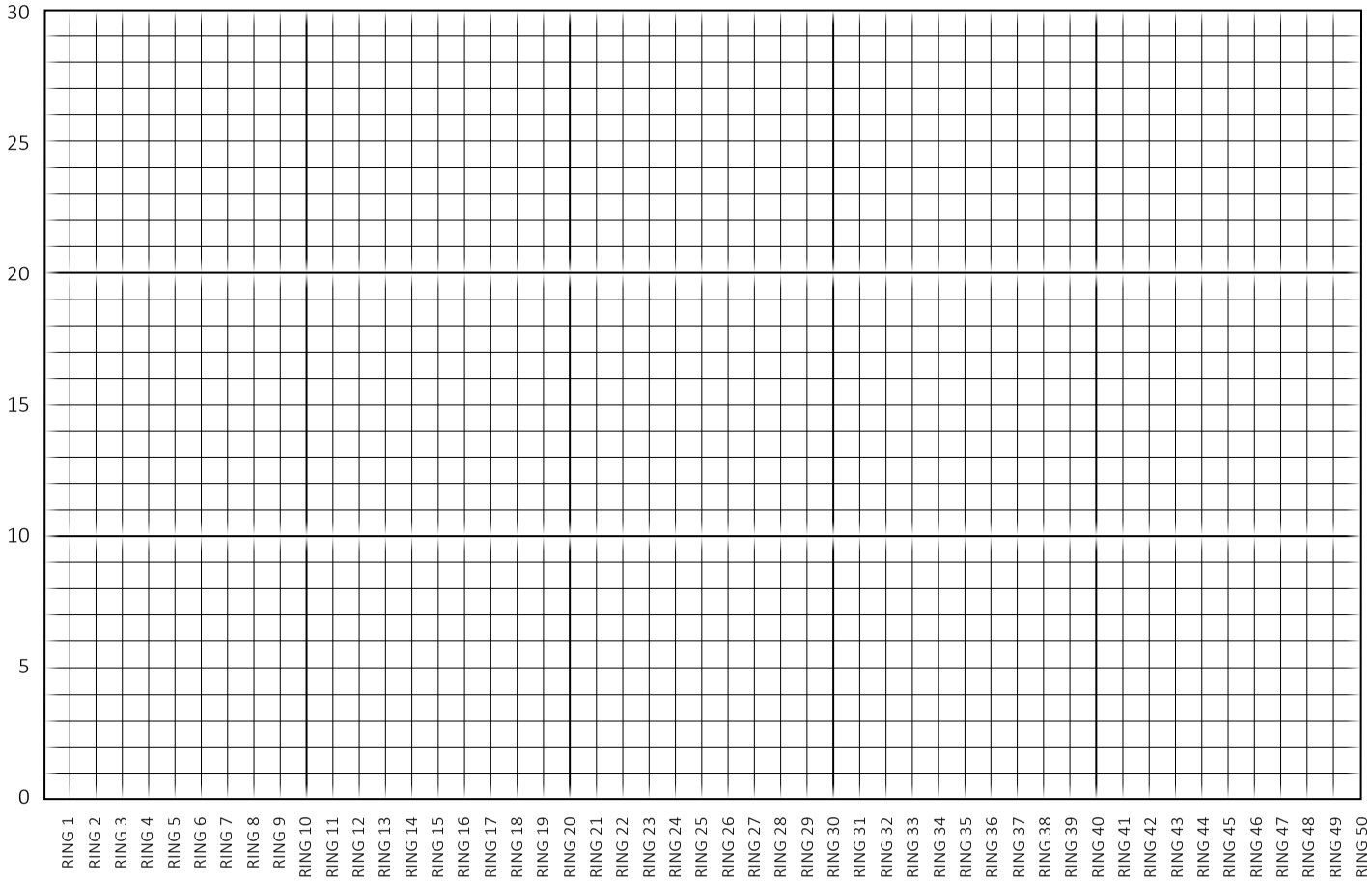
Sequence Table

Ring 1	12	Ring 11	21	Ring 21	17	Ring 31	17	Ring 41	14
Ring 2	9	Ring 12	24	Ring 22	15	Ring 32	13	Ring 42	14
Ring 3	5	Ring 13	23	Ring 23	12	Ring 33	10	Ring 43	13
Ring 4	10	Ring 14	25	Ring 24	13	Ring 34	8	Ring 44	12
Ring 5	15	Ring 15	23	Ring 25	11	Ring 35	10	Ring 45	10
Ring 6	18	Ring 16	25	Ring 26	13	Ring 36	13	Ring 46	5
Ring 7	23	Ring 17	19	Ring 27	10	Ring 37	10	Ring 47	17
Ring 8	19	Ring 18	21	Ring 28	13	Ring 38	13	Ring 48	12
Ring 9	23	Ring 19	10	Ring 29	15	Ring 39	15	Ring 49	10
Ring 10	21	Ring 20	11	Ring 30	15	Ring 40	12	Ring 50	9

Measurements in mm

Sequence graph recording sheet

N1



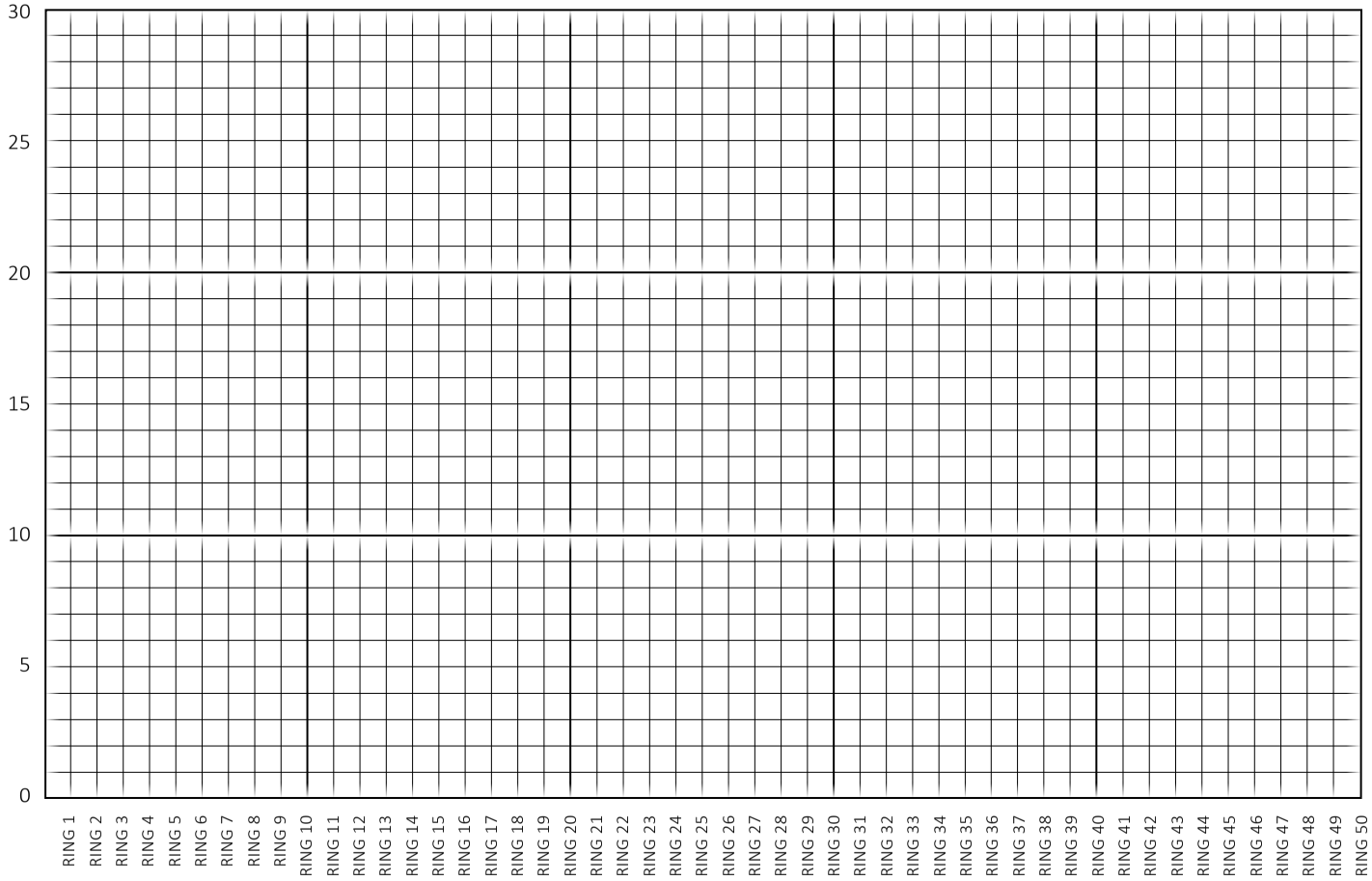
Sequence Table

Ring 1	10	Ring 11	10	Ring 21	5	Ring 31	23	Ring 41	13
Ring 2	13	Ring 12	5	Ring 22	7	Ring 32	20	Ring 42	16
Ring 3	10	Ring 13	17	Ring 23	4	Ring 33	25	Ring 43	10
Ring 4	13	Ring 14	12	Ring 24	9	Ring 34	16	Ring 44	9
Ring 5	15	Ring 15	10	Ring 25	9	Ring 35	18	Ring 45	8
Ring 6	12	Ring 16	9	Ring 26	11	Ring 36	16	Ring 46	15
Ring 7	14	Ring 17	7	Ring 27	20	Ring 37	18	Ring 47	16
Ring 8	14	Ring 18	10	Ring 28	18	Ring 38	16	Ring 48	19
Ring 9	13	Ring 19	6	Ring 29	23	Ring 39	13	Ring 49	16
Ring 10	12	Ring 20	8	Ring 30	20	Ring 40	16	Ring 50	22

Measurements in mm

Sequence graph recording sheet

D2



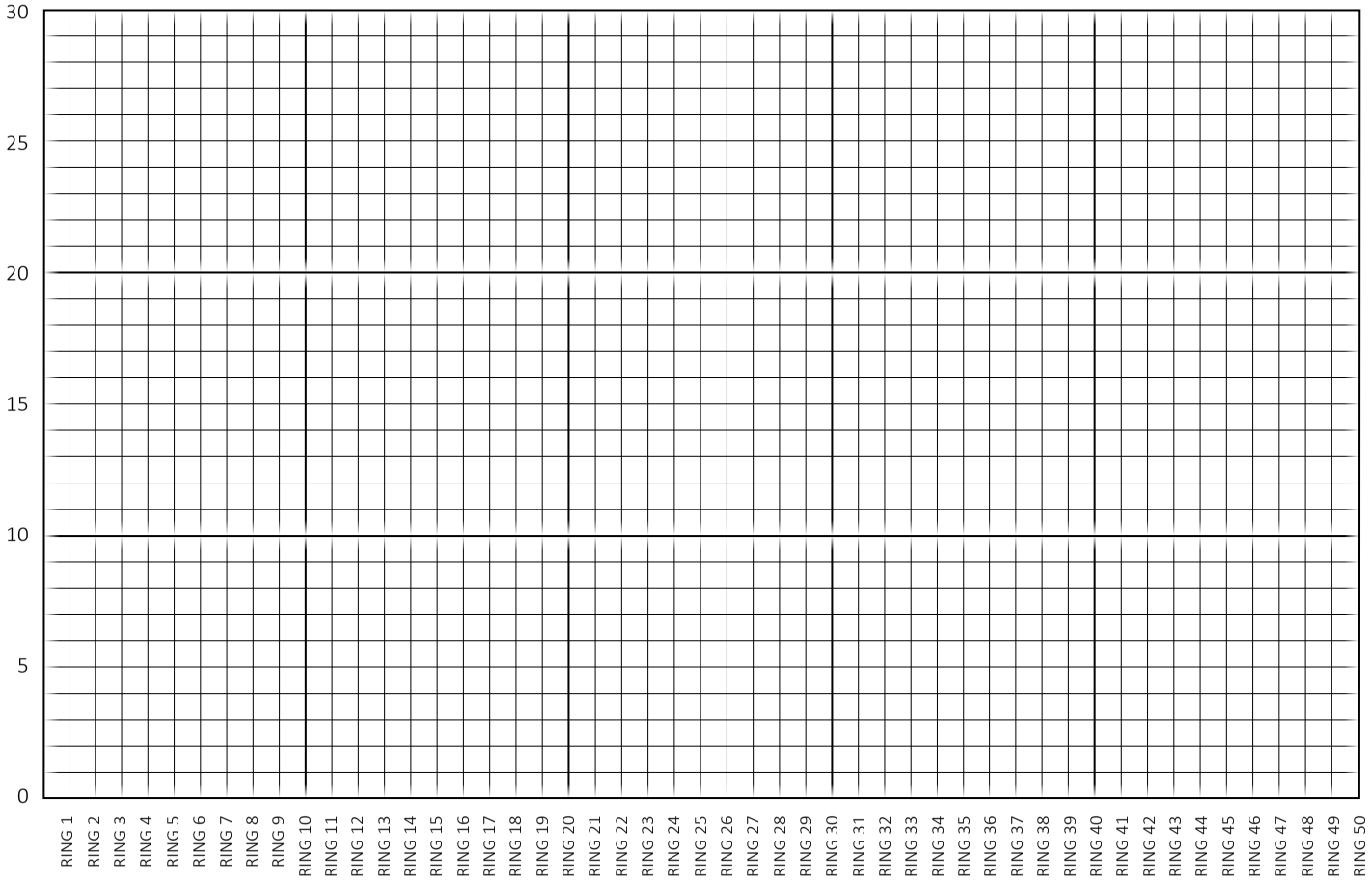
Sequence Table

Ring 1	12	Ring 11	24	Ring 21	17	Ring 31	17	Ring 41	14
Ring 2	9	Ring 12	23	Ring 22	15	Ring 32	13	Ring 42	14
Ring 3	5	Ring 13	25	Ring 23	12	Ring 33	10	Ring 43	13
Ring 4	10	Ring 14	23	Ring 24	13	Ring 34	8	Ring 44	12
Ring 5	15	Ring 15	25	Ring 25	11	Ring 35	10	Ring 45	10
Ring 6	18	Ring 16	19	Ring 26	13	Ring 36	13	Ring 46	5
Ring 7	23	Ring 17	21	Ring 27	10	Ring 37	10	Ring 47	17
Ring 8	19	Ring 18	10	Ring 28	13	Ring 38	13	Ring 48	12
Ring 9	23	Ring 19	11	Ring 29	15	Ring 39	15	Ring 49	10
Ring 10	21	Ring 20	15	Ring 30	15	Ring 40	12	Ring 50	9

Measurements in mm

Sequence graph recording sheet

R1



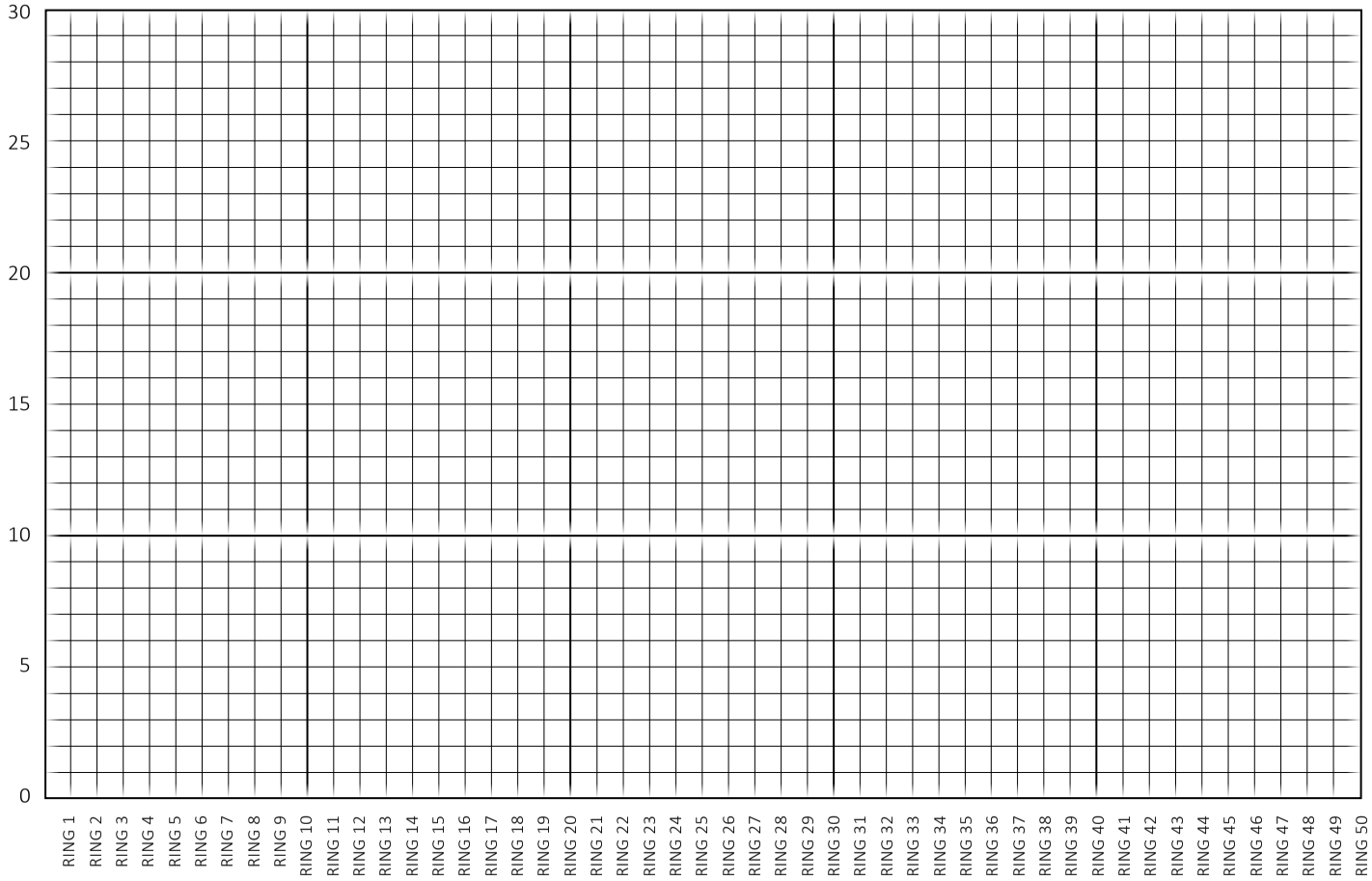
Sequence Table

Ring 1	21	Ring 11	11	Ring 21	13	Ring 31	25	Ring 41	24
Ring 2	21	Ring 12	6	Ring 22	17	Ring 32	23	Ring 42	27
Ring 3	15	Ring 13	10	Ring 23	10	Ring 33	20	Ring 43	24
Ring 4	11	Ring 14	12	Ring 24	28	Ring 34	20	Ring 44	26
Ring 5	10	Ring 15	14	Ring 25	17	Ring 35	24	Ring 45	20
Ring 6	7	Ring 16	15	Ring 26	8	Ring 36	23	Ring 46	23
Ring 7	13	Ring 17	12	Ring 27	17	Ring 37	22	Ring 47	18
Ring 8	15	Ring 18	15	Ring 28	12	Ring 38	10	Ring 48	18
Ring 9	12	Ring 19	12	Ring 29	17	Ring 39	23	Ring 49	18
Ring 10	8	Ring 20	17	Ring 30	20	Ring 40	25	Ring 50	12

Measurements in mm

Sequence graph recording sheet

O1



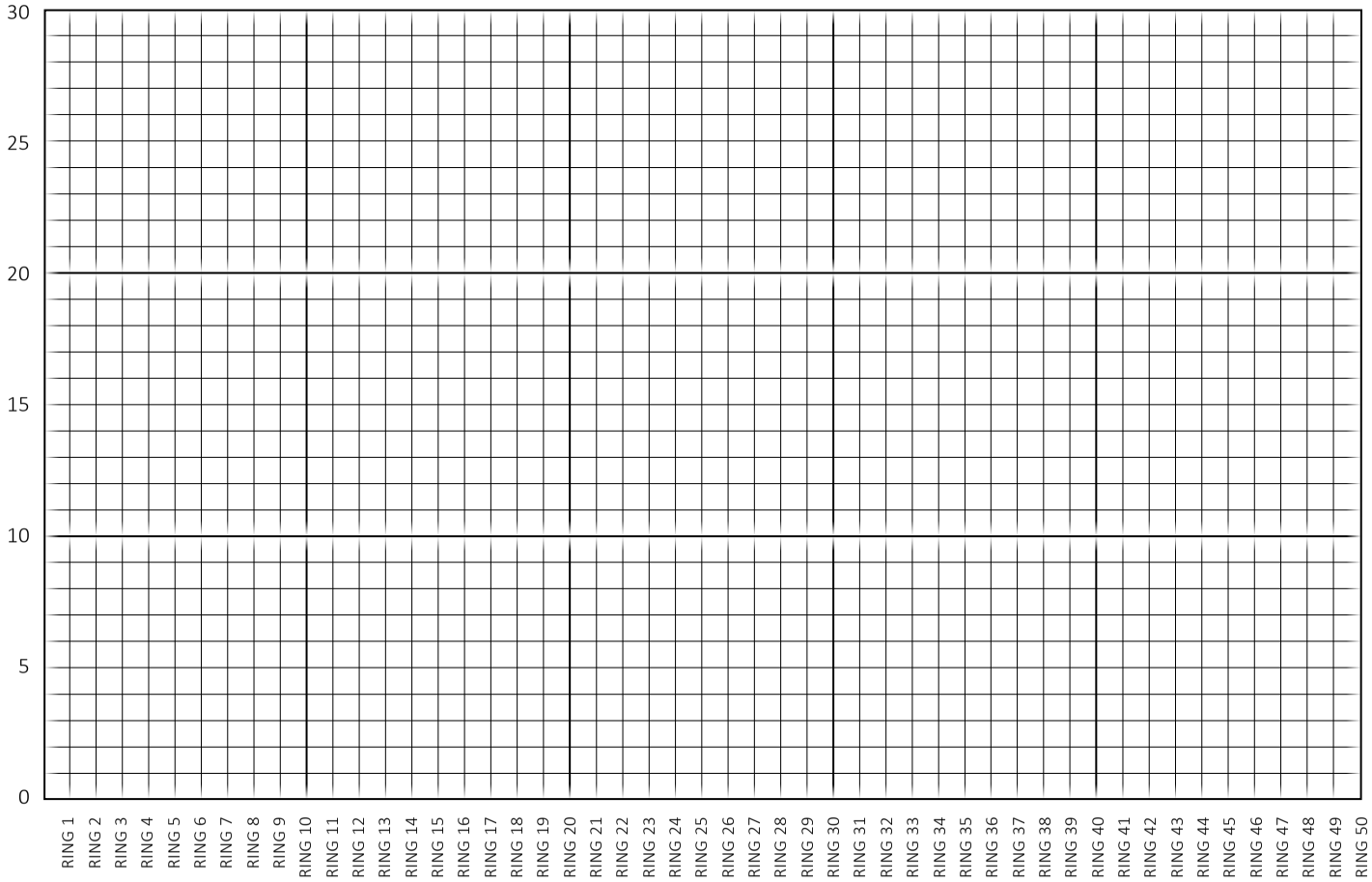
Sequence Table

Ring 1	24	Ring 11	20	Ring 21	17	Ring 31	11	Ring 41	14
Ring 2	23	Ring 12	23	Ring 22	21	Ring 32	20	Ring 42	17
Ring 3	22	Ring 13	18	Ring 23	18	Ring 33	14	Ring 43	16
Ring 4	10	Ring 14	18	Ring 24	16	Ring 34	8	Ring 44	20
Ring 5	23	Ring 15	18	Ring 25	15	Ring 35	8	Ring 45	18
Ring 6	25	Ring 16	12	Ring 26	4	Ring 36	5	Ring 46	25
Ring 7	24	Ring 17	15	Ring 27	12	Ring 37	12	Ring 47	20
Ring 8	27	Ring 18	18	Ring 28	14	Ring 38	15	Ring 48	15
Ring 9	24	Ring 19	15	Ring 29	10	Ring 39	12	Ring 49	13
Ring 10	26	Ring 20	20	Ring 30	15	Ring 40	17	Ring 50	17

Measurements in mm

Sequence graph recording sheet

C1



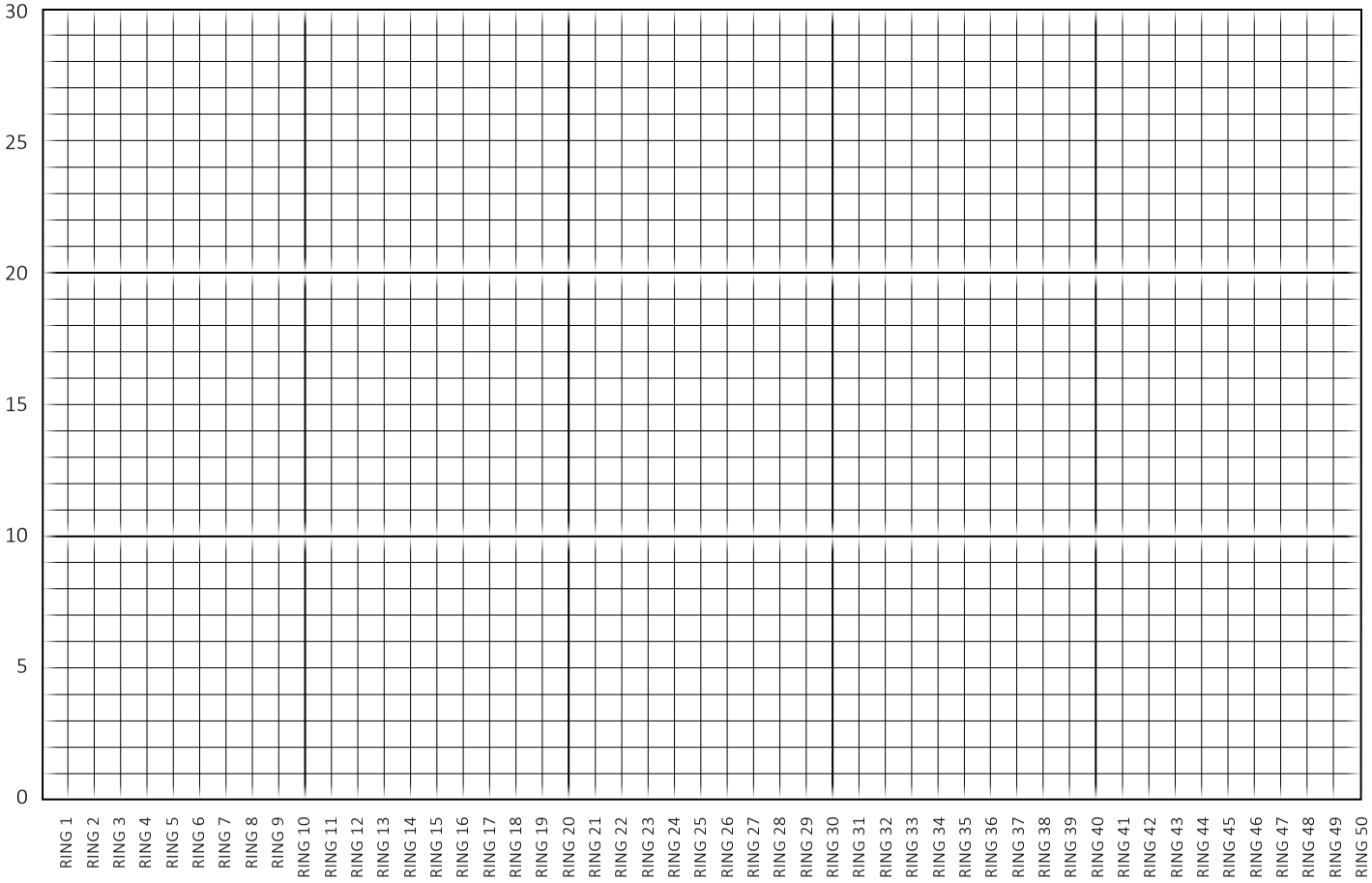
Sequence Table

Ring 1	8	Ring 11	18	Ring 21	17	Ring 31	19	Ring 41	10
Ring 2	5	Ring 12	25	Ring 22	10	Ring 32	16	Ring 42	8
Ring 3	12	Ring 13	20	Ring 23	24	Ring 33	21	Ring 43	7
Ring 4	15	Ring 14	15	Ring 24	26	Ring 34	16	Ring 44	10
Ring 5	12	Ring 15	13	Ring 25	25	Ring 35	17	Ring 45	16
Ring 6	17	Ring 16	17	Ring 26	16	Ring 36	18	Ring 46	15
Ring 7	14	Ring 17	15	Ring 27	5	Ring 37	13	Ring 47	14
Ring 8	17	Ring 18	16	Ring 28	12	Ring 38	15	Ring 48	7
Ring 9	16	Ring 19	15	Ring 29	10	Ring 39	16	Ring 49	15
Ring 10	20	Ring 20	14	Ring 30	17	Ring 40	18	Ring 50	17

Measurements in mm

Sequence graph recording sheet

H1



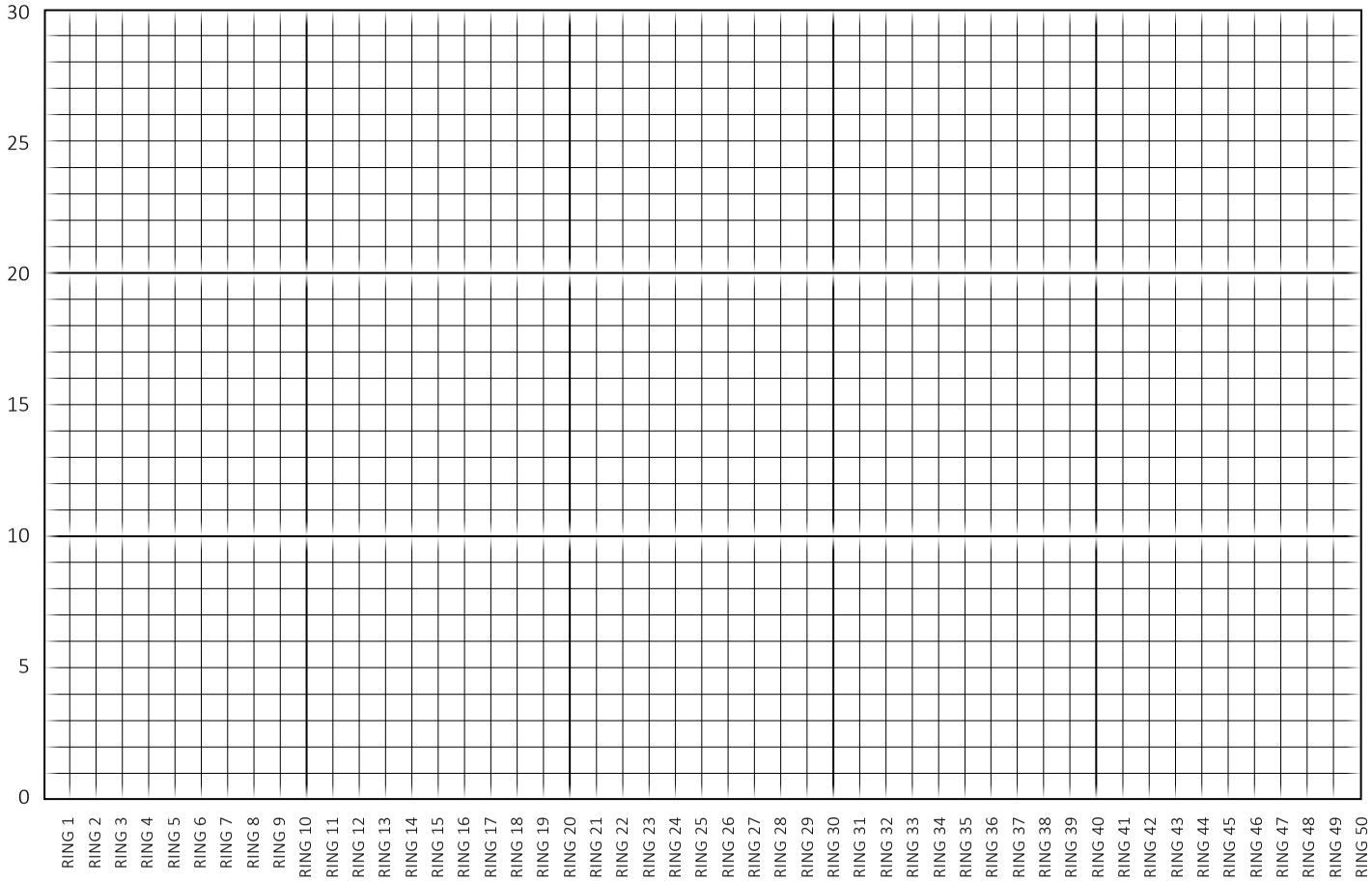
Sequence Table

Ring 1	17	Ring 11	16	Ring 21	25	Ring 31	12	Ring 41	15
Ring 2	18	Ring 12	15	Ring 22	15	Ring 32	10	Ring 42	2
Ring 3	13	Ring 13	14	Ring 23	20	Ring 33	8	Ring 43	10
Ring 4	15	Ring 14	7	Ring 24	16	Ring 34	10	Ring 44	5
Ring 5	16	Ring 15	15	Ring 25	18	Ring 35	7	Ring 45	25
Ring 6	18	Ring 16	17	Ring 26	16	Ring 36	9	Ring 46	20
Ring 7	10	Ring 17	20	Ring 27	15	Ring 37	7	Ring 47	25
Ring 8	8	Ring 18	18	Ring 28	17	Ring 38	27	Ring 48	30
Ring 9	7	Ring 19	21	Ring 29	13	Ring 39	11	Ring 49	25
Ring 10	10	Ring 20	19	Ring 30	10	Ring 40	2	Ring 50	20

Measurements in mm

Sequence graph recording sheet

R2



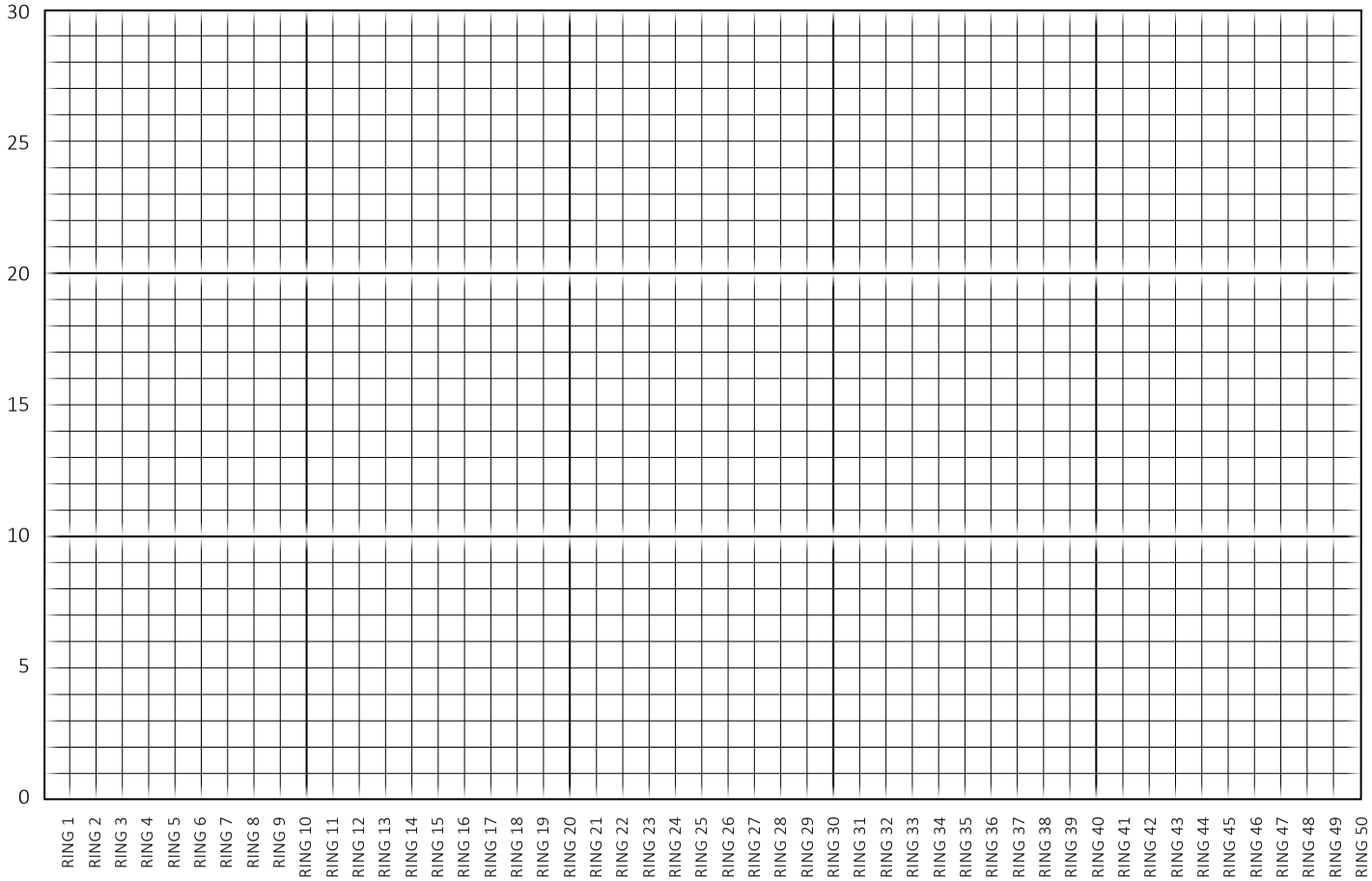
Sequence Table

Ring 1	7	Ring 11	25	Ring 21	2	Ring 31	10	Ring 41	14
Ring 2	9	Ring 12	20	Ring 22	5	Ring 32	13	Ring 42	13
Ring 3	7	Ring 13	25	Ring 23	15	Ring 33	1	Ring 43	10
Ring 4	27	Ring 14	30	Ring 24	10	Ring 34	9	Ring 44	13
Ring 5	11	Ring 15	25	Ring 25	17	Ring 35	11	Ring 45	3
Ring 6	2	Ring 16	20	Ring 26	15	Ring 36	15	Ring 46	9
Ring 7	15	Ring 17	15	Ring 27	25	Ring 37	10	Ring 47	3
Ring 8	2	Ring 18	25	Ring 28	15	Ring 38	15	Ring 48	6
Ring 9	10	Ring 19	20	Ring 29	8	Ring 39	20	Ring 49	8
Ring 10	5	Ring 20	5	Ring 30	15	Ring 40	15	Ring 50	10

Measurements in mm

Sequence graph recording sheet

O2



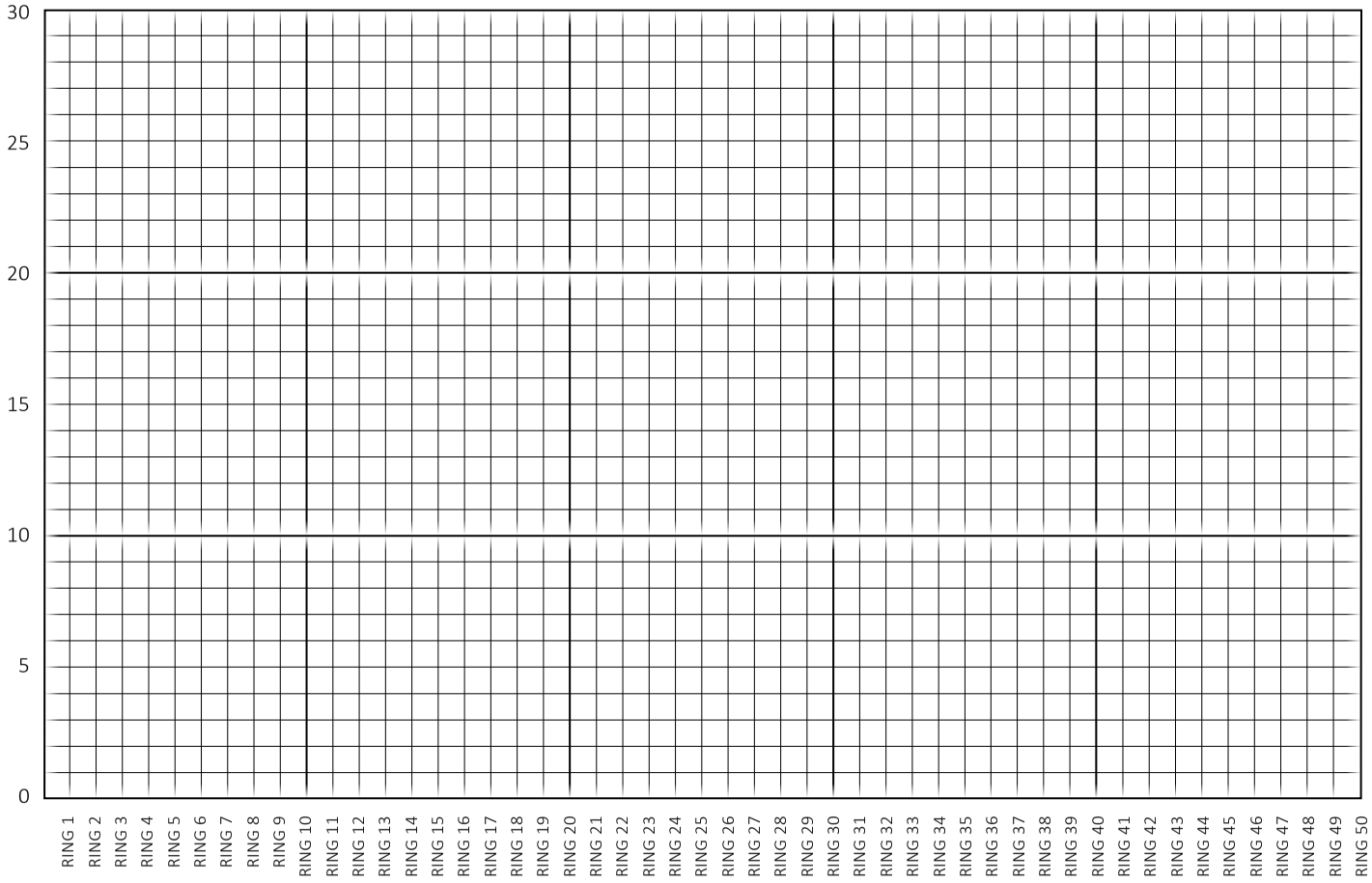
Sequence Table

Ring 1	11	Ring 11	3	Ring 21	13	Ring 31	15	Ring 41	15
Ring 2	15	Ring 12	9	Ring 22	5	Ring 32	10	Ring 42	10
Ring 3	10	Ring 13	3	Ring 23	5	Ring 33	20	Ring 43	5
Ring 4	15	Ring 14	6	Ring 24	5	Ring 34	13	Ring 44	11
Ring 5	20	Ring 15	8	Ring 25	3	Ring 35	16	Ring 45	12
Ring 6	15	Ring 16	10	Ring 26	5	Ring 36	5	Ring 46	13
Ring 7	14	Ring 17	16	Ring 27	12	Ring 37	9	Ring 47	5
Ring 8	13	Ring 18	7	Ring 28	7	Ring 38	3	Ring 48	2
Ring 9	10	Ring 19	7	Ring 29	11	Ring 39	13	Ring 49	2
Ring 10	13	Ring 20	7	Ring 30	7	Ring 40	8	Ring 50	2

Measurements in mm

Sequence graph recording sheet

N2



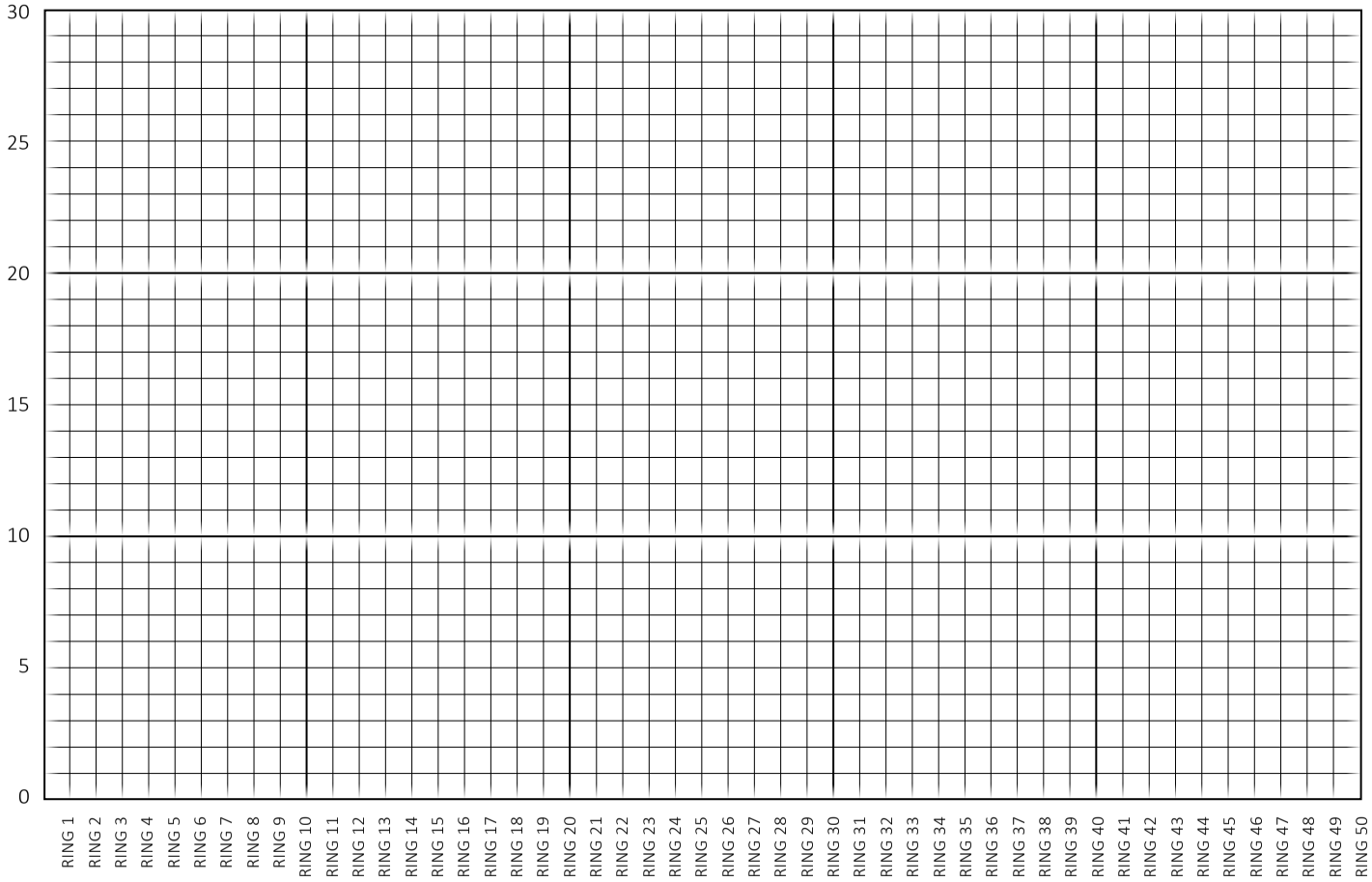
Sequence Table

Ring 1	16	Ring 11	12	Ring 21	9	Ring 31	23	Ring 41	23
Ring 2	5	Ring 12	13	Ring 22	10	Ring 32	20	Ring 42	25
Ring 3	9	Ring 13	5	Ring 23	15	Ring 33	25	Ring 43	27
Ring 4	3	Ring 14	2	Ring 24	12	Ring 34	17	Ring 44	24
Ring 5	13	Ring 15	2	Ring 25	25	Ring 35	23	Ring 45	28
Ring 6	8	Ring 16	2	Ring 26	22	Ring 36	19	Ring 46	22
Ring 7	15	Ring 17	5	Ring 27	28	Ring 37	28	Ring 47	15
Ring 8	10	Ring 18	15	Ring 28	20	Ring 38	16	Ring 48	21
Ring 9	5	Ring 19	8	Ring 29	23	Ring 39	18	Ring 49	18
Ring 10	11	Ring 20	5	Ring 30	20	Ring 40	15	Ring 50	23

Measurements in mm

Sequence graph recording sheet

O3



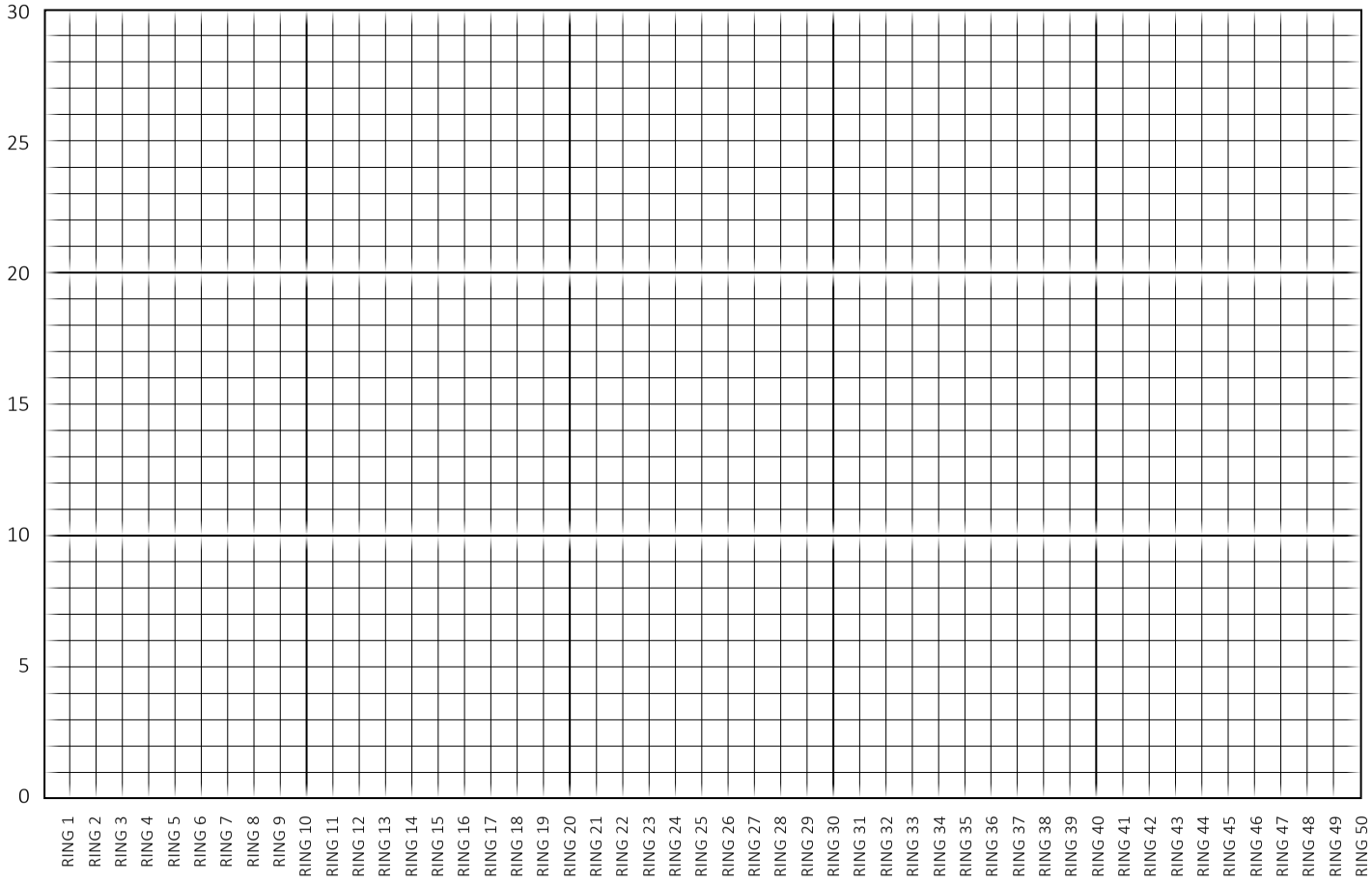
Sequence Table

Ring 1	23	Ring 11	28	Ring 21	18	Ring 31	20	Ring 41	20
Ring 2	19	Ring 12	22	Ring 22	17	Ring 32	19	Ring 42	23
Ring 3	28	Ring 13	15	Ring 23	14	Ring 33	18	Ring 43	20
Ring 4	16	Ring 14	21	Ring 24	25	Ring 34	17	Ring 44	20
Ring 5	18	Ring 15	18	Ring 25	17	Ring 35	25	Ring 45	20
Ring 6	15	Ring 16	23	Ring 26	23	Ring 36	17	Ring 46	20
Ring 7	23	Ring 17	18	Ring 27	13	Ring 37	18	Ring 47	25
Ring 8	25	Ring 18	21	Ring 28	20	Ring 38	19	Ring 48	24
Ring 9	27	Ring 19	18	Ring 29	21	Ring 39	20	Ring 49	24
Ring 10	24	Ring 20	19	Ring 30	25	Ring 40	12	Ring 50	25

Measurements in mm

Sequence graph recording sheet

L1



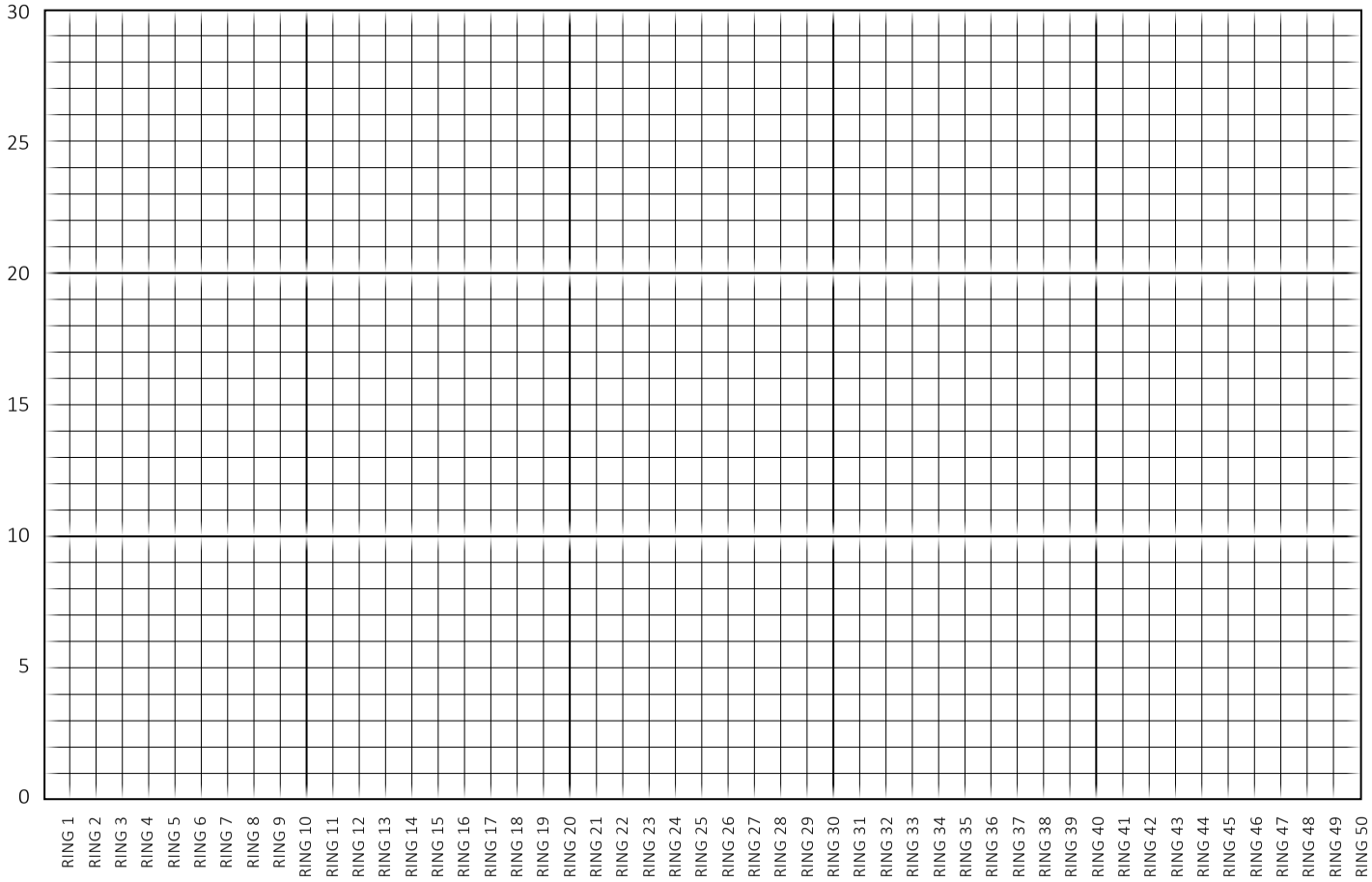
Sequence Table

Ring 1	25	Ring 11	20	Ring 21	20	Ring 31	20	Ring 41	13
Ring 2	17	Ring 12	20	Ring 22	15	Ring 32	13	Ring 42	15
Ring 3	18	Ring 13	25	Ring 23	20	Ring 33	17	Ring 43	18
Ring 4	19	Ring 14	24	Ring 24	25	Ring 34	13	Ring 44	16
Ring 5	20	Ring 15	24	Ring 25	20	Ring 35	16	Ring 45	26
Ring 6	12	Ring 16	25	Ring 26	23	Ring 36	13	Ring 46	16
Ring 7	20	Ring 17	28	Ring 27	20	Ring 37	15	Ring 47	10
Ring 8	23	Ring 18	15	Ring 28	17	Ring 38	10	Ring 48	7
Ring 9	20	Ring 19	18	Ring 29	20	Ring 39	13	Ring 49	15
Ring 10	20	Ring 20	13	Ring 30	22	Ring 40	8	Ring 50	15

Measurements in mm

Sequence graph recording sheet

O4



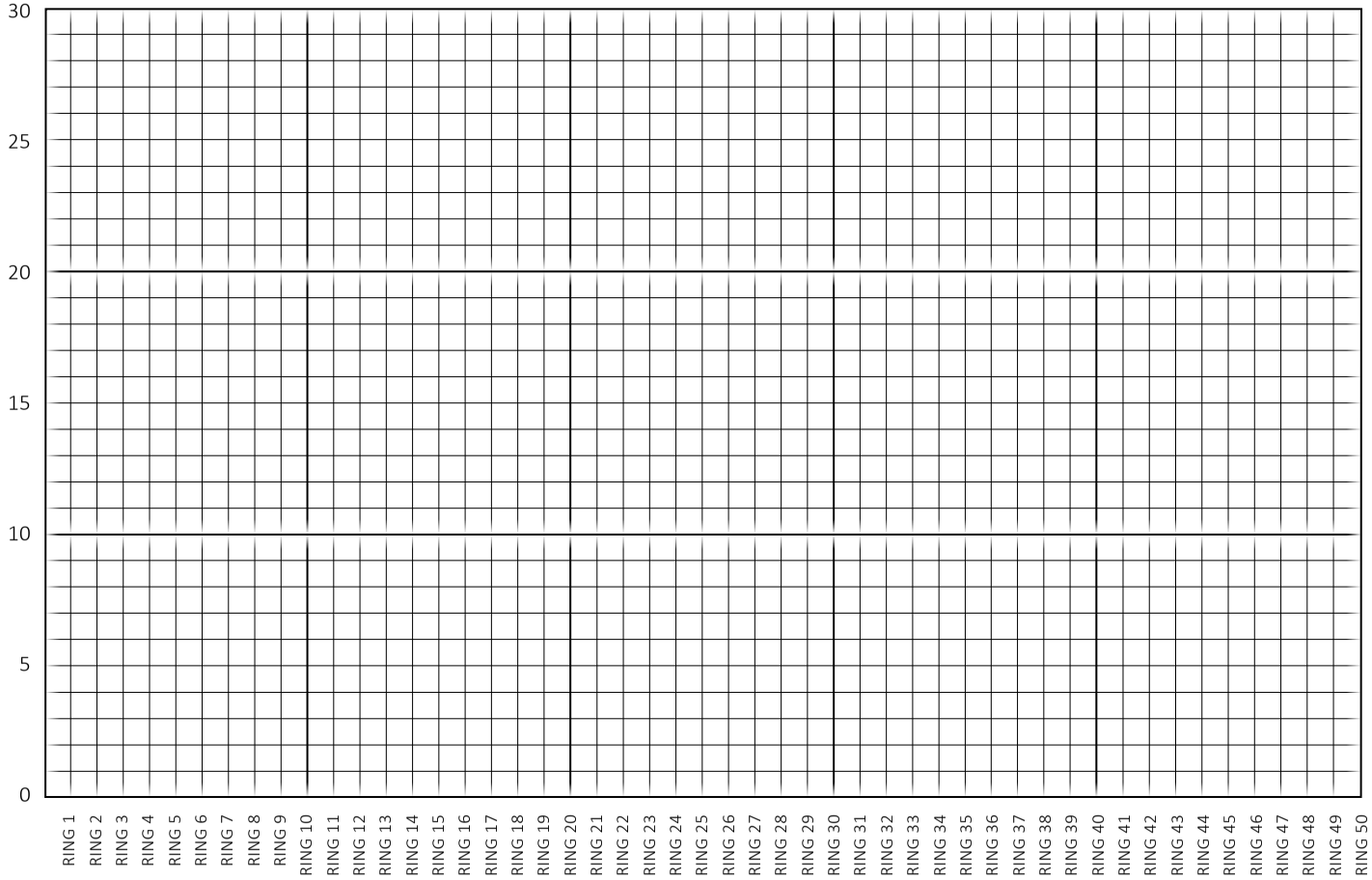
Sequence Table

Ring 1	16	Ring 11	26	Ring 21	15	Ring 31	12	Ring 41	20
Ring 2	13	Ring 12	16	Ring 22	12	Ring 32	11	Ring 42	23
Ring 3	15	Ring 13	10	Ring 23	15	Ring 33	10	Ring 43	19
Ring 4	10	Ring 14	7	Ring 24	7	Ring 34	6	Ring 44	23
Ring 5	13	Ring 15	15	Ring 25	12	Ring 35	12	Ring 45	19
Ring 6	8	Ring 16	15	Ring 26	20	Ring 36	13	Ring 46	15
Ring 7	13	Ring 17	21	Ring 27	23	Ring 37	15	Ring 47	5
Ring 8	15	Ring 18	15	Ring 28	25	Ring 38	20	Ring 48	11
Ring 9	18	Ring 19	10	Ring 29	23	Ring 39	17	Ring 49	7
Ring 10	16	Ring 20	17	Ring 30	15	Ring 40	24	Ring 50	10

Measurements in mm

Sequence graph recording sheet

G1



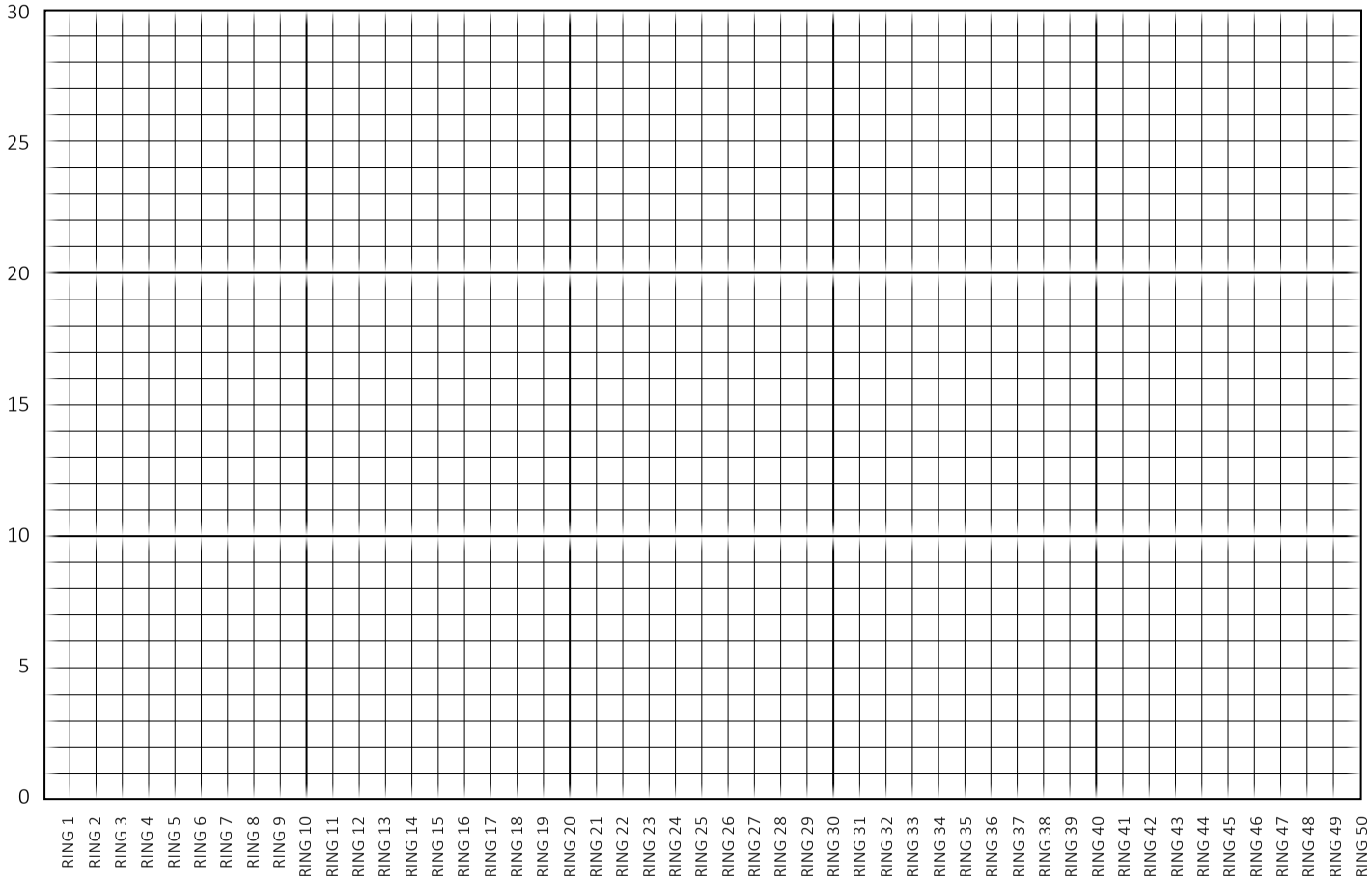
Sequence Table

Ring 1	12	Ring 11	19	Ring 21	4	Ring 31	20	Ring 41	15
Ring 2	13	Ring 12	15	Ring 22	10	Ring 32	15	Ring 42	12
Ring 3	15	Ring 13	5	Ring 23	15	Ring 33	18	Ring 43	18
Ring 4	20	Ring 14	11	Ring 24	17	Ring 34	20	Ring 44	14
Ring 5	17	Ring 15	7	Ring 25	15	Ring 35	21	Ring 45	20
Ring 6	24	Ring 16	10	Ring 26	19	Ring 36	10	Ring 46	15
Ring 7	20	Ring 17	5	Ring 27	7	Ring 37	3	Ring 47	11
Ring 8	23	Ring 18	7	Ring 28	17	Ring 38	10	Ring 48	15
Ring 9	19	Ring 19	4	Ring 29	19	Ring 39	14	Ring 49	6
Ring 10	23	Ring 20	7	Ring 30	12	Ring 40	11	Ring 50	10

Measurements in mm

Sequence graph recording sheet

Y1



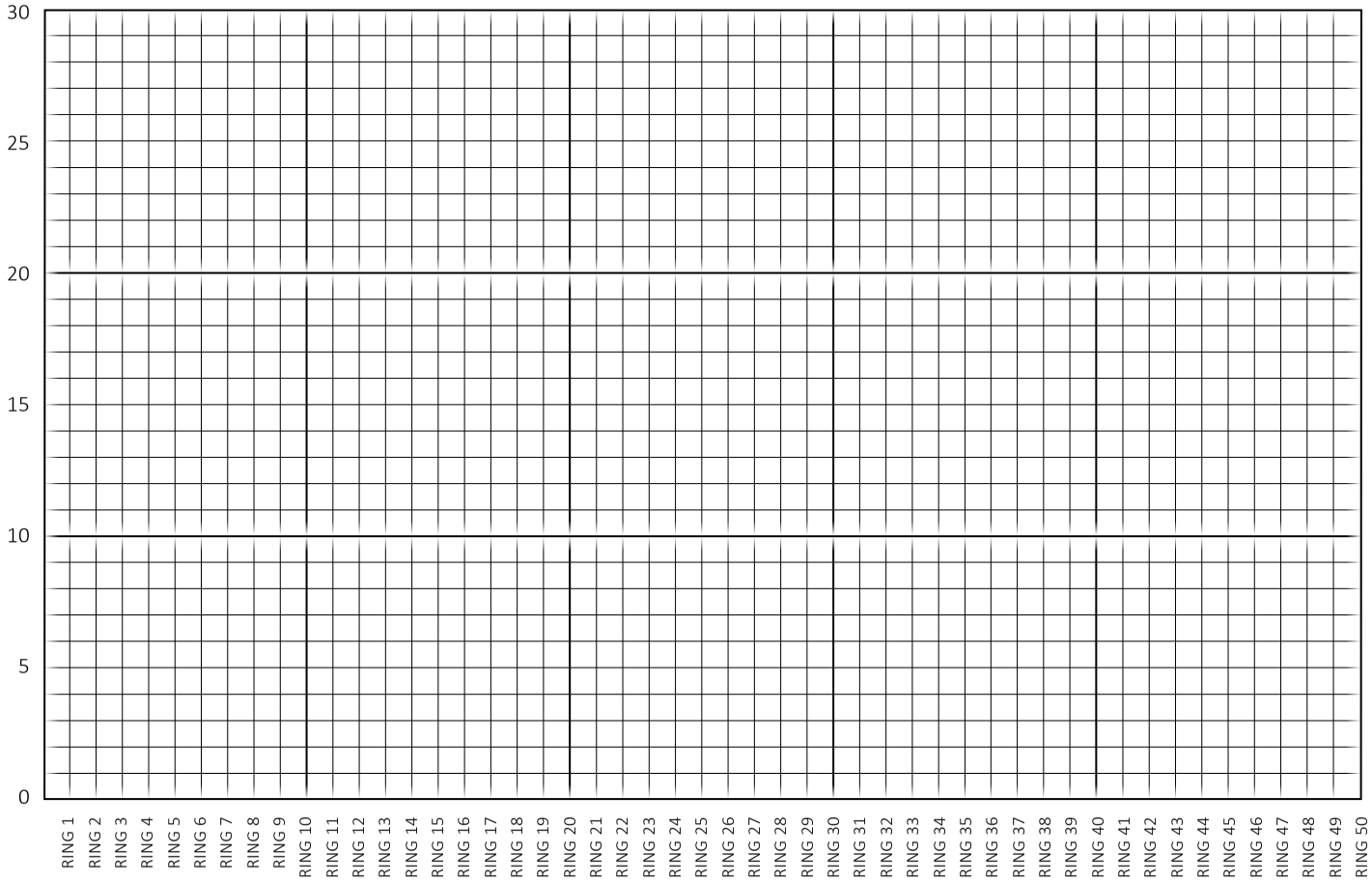
Sequence Table

Ring 1	21	Ring 11	20	Ring 21	6	Ring 31	15	Ring 41	18
Ring 2	10	Ring 12	15	Ring 22	13	Ring 32	20	Ring 42	20
Ring 3	3	Ring 13	11	Ring 23	20	Ring 33	22	Ring 43	19
Ring 4	10	Ring 14	15	Ring 24	13	Ring 34	13	Ring 44	18
Ring 5	14	Ring 15	6	Ring 25	15	Ring 35	17	Ring 45	28
Ring 6	11	Ring 16	10	Ring 26	17	Ring 36	14	Ring 46	25
Ring 7	15	Ring 17	8	Ring 27	20	Ring 37	22	Ring 47	27
Ring 8	12	Ring 18	7	Ring 28	15	Ring 38	20	Ring 48	18
Ring 9	18	Ring 19	2	Ring 29	3	Ring 39	22	Ring 49	15
Ring 10	14	Ring 20	10	Ring 30	10	Ring 40	16	Ring 50	7

Measurements in mm

Sequence graph recording sheet

T1



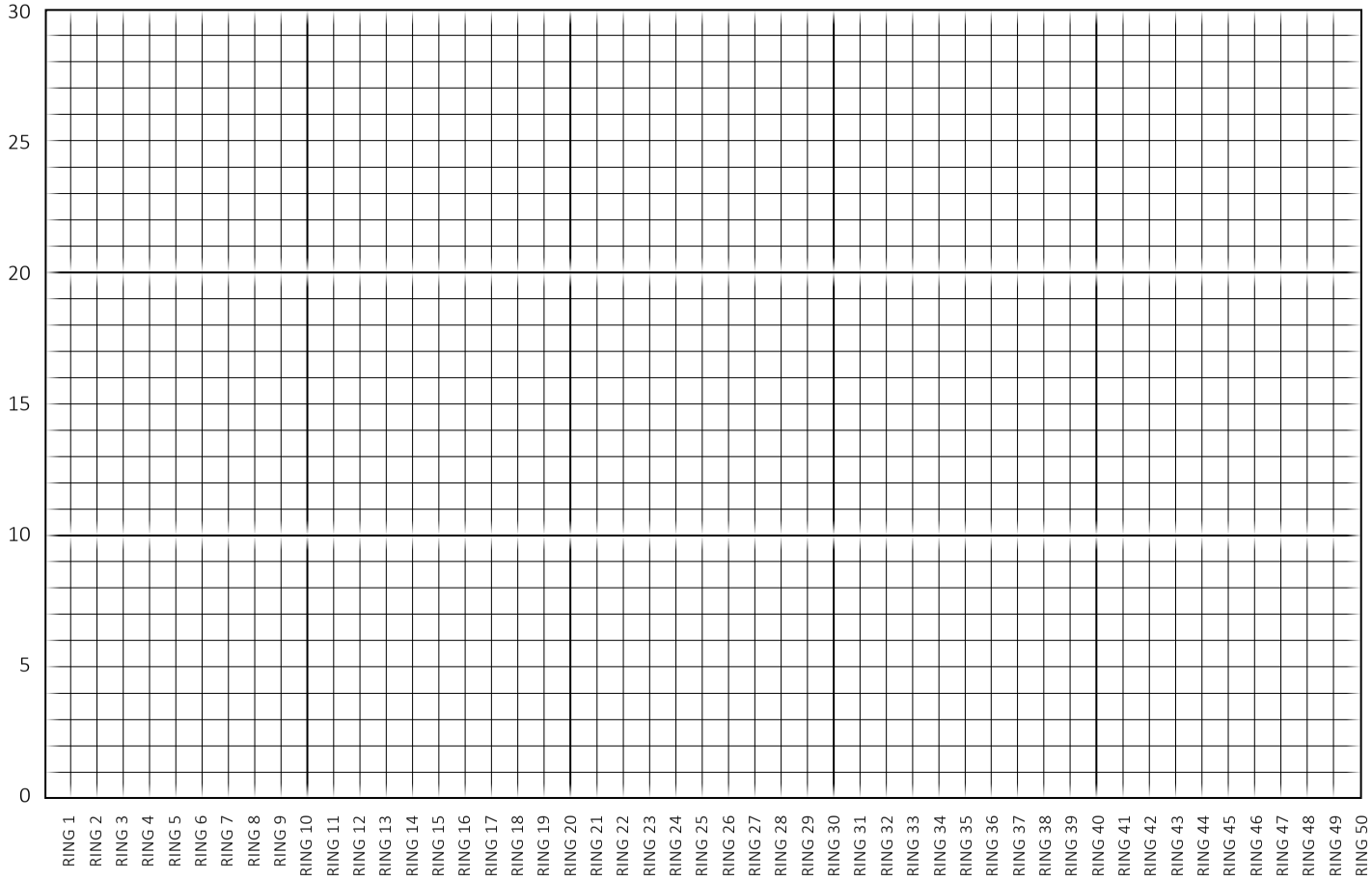
Sequence Table

Ring 1	17	Ring 11	28	Ring 21	20	Ring 31	13	Ring 41	5
Ring 2	14	Ring 12	25	Ring 22	15	Ring 32	17	Ring 42	10
Ring 3	22	Ring 13	27	Ring 23	21	Ring 33	20	Ring 43	7
Ring 4	20	Ring 14	18	Ring 24	12	Ring 34	18	Ring 44	12
Ring 5	22	Ring 15	15	Ring 25	17	Ring 35	17	Ring 45	5
Ring 6	16	Ring 16	7	Ring 26	25	Ring 36	15	Ring 46	2
Ring 7	18	Ring 17	25	Ring 27	15	Ring 37	9	Ring 47	7
Ring 8	20	Ring 18	28	Ring 28	5	Ring 38	5	Ring 48	2
Ring 9	19	Ring 19	26	Ring 29	8	Ring 39	9	Ring 49	7
Ring 10	18	Ring 20	30	Ring 30	10	Ring 40	2	Ring 50	2

Measurements in mm

Sequence graph recording sheet

R3



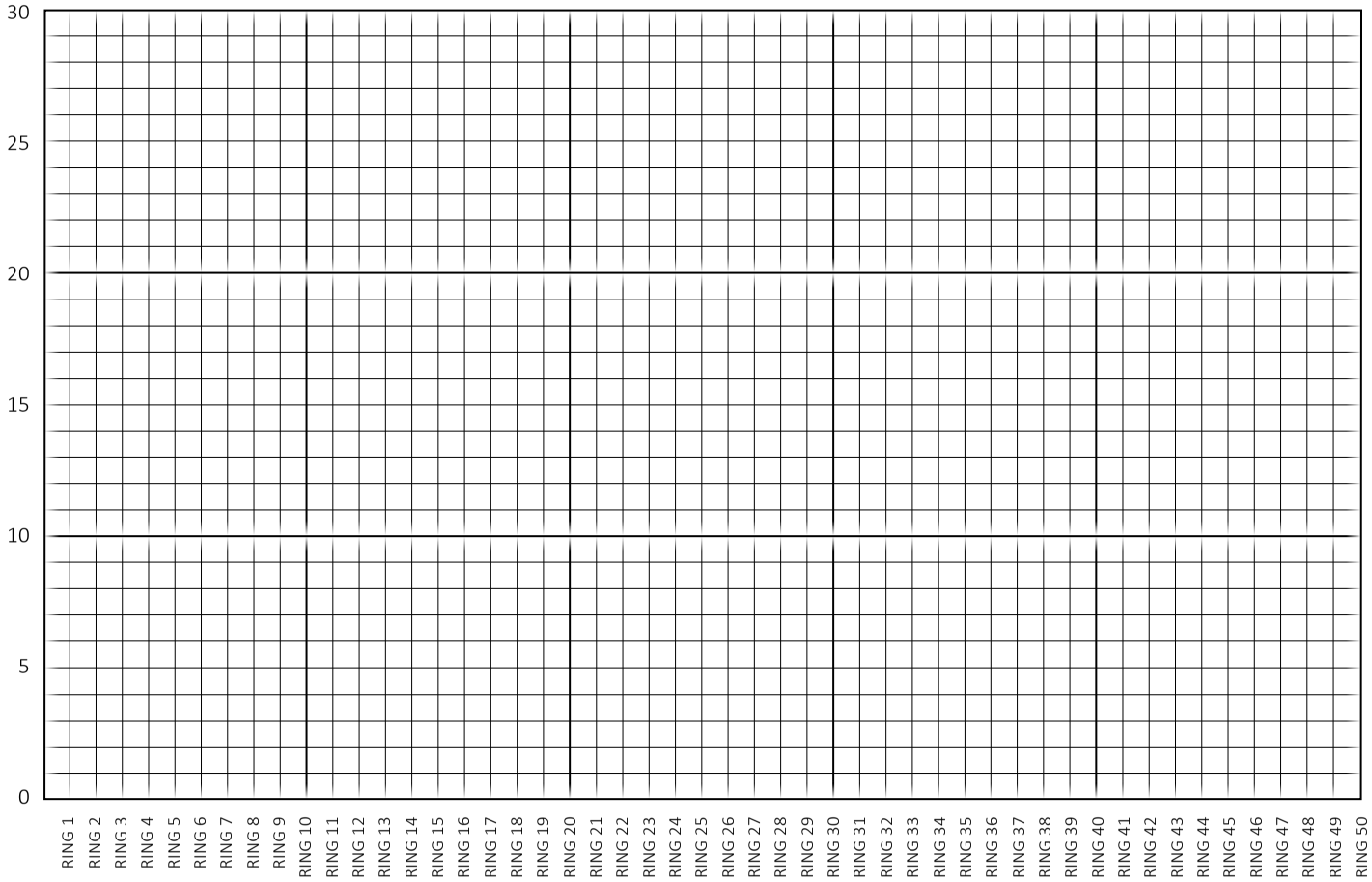
Sequence Table

Ring 1	17	Ring 11	5	Ring 21	7	Ring 31	12	Ring 41	25
Ring 2	15	Ring 12	2	Ring 22	9	Ring 32	18	Ring 42	12
Ring 3	9	Ring 13	7	Ring 23	9	Ring 33	14	Ring 43	7
Ring 4	5	Ring 14	2	Ring 24	9	Ring 34	5	Ring 44	10
Ring 5	9	Ring 15	7	Ring 25	9	Ring 35	8	Ring 45	7
Ring 6	2	Ring 16	2	Ring 26	5	Ring 36	12	Ring 46	12
Ring 7	5	Ring 17	7	Ring 27	10	Ring 37	15	Ring 47	8
Ring 8	10	Ring 18	3	Ring 28	13	Ring 38	12	Ring 48	6
Ring 9	7	Ring 19	10	Ring 29	7	Ring 39	15	Ring 49	5
Ring 10	12	Ring 20	5	Ring 30	13	Ring 40	12	Ring 50	2

Measurements in mm

Sequence graph recording sheet

E2



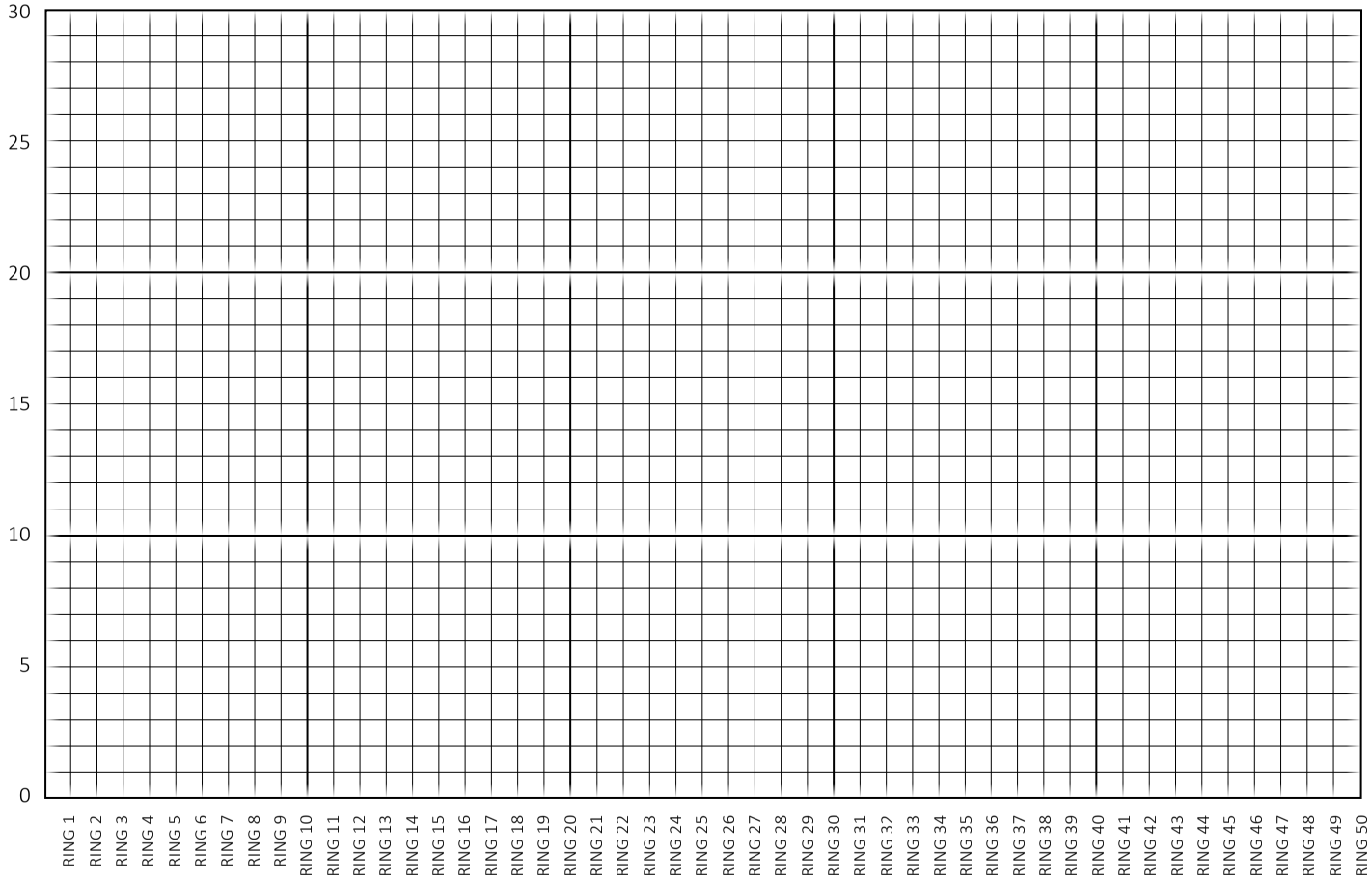
Sequence Table

Ring 1	8	Ring 11	7	Ring 21	18	Ring 31	12	Ring 41	9
Ring 2	12	Ring 12	12	Ring 22	15	Ring 32	20	Ring 42	13
Ring 3	15	Ring 13	8	Ring 23	15	Ring 33	9	Ring 43	12
Ring 4	12	Ring 14	6	Ring 24	15	Ring 34	7	Ring 44	11
Ring 5	15	Ring 15	5	Ring 25	13	Ring 35	5	Ring 45	17
Ring 6	12	Ring 16	2	Ring 26	16	Ring 36	10	Ring 46	14
Ring 7	25	Ring 17	10	Ring 27	11	Ring 37	5	Ring 47	20
Ring 8	12	Ring 18	15	Ring 28	17	Ring 38	15	Ring 48	11
Ring 9	7	Ring 19	17	Ring 29	9	Ring 39	13	Ring 49	16
Ring 10	10	Ring 20	19	Ring 30	17	Ring 40	10	Ring 50	20

Measurements in mm

Sequence graph recording sheet

E3



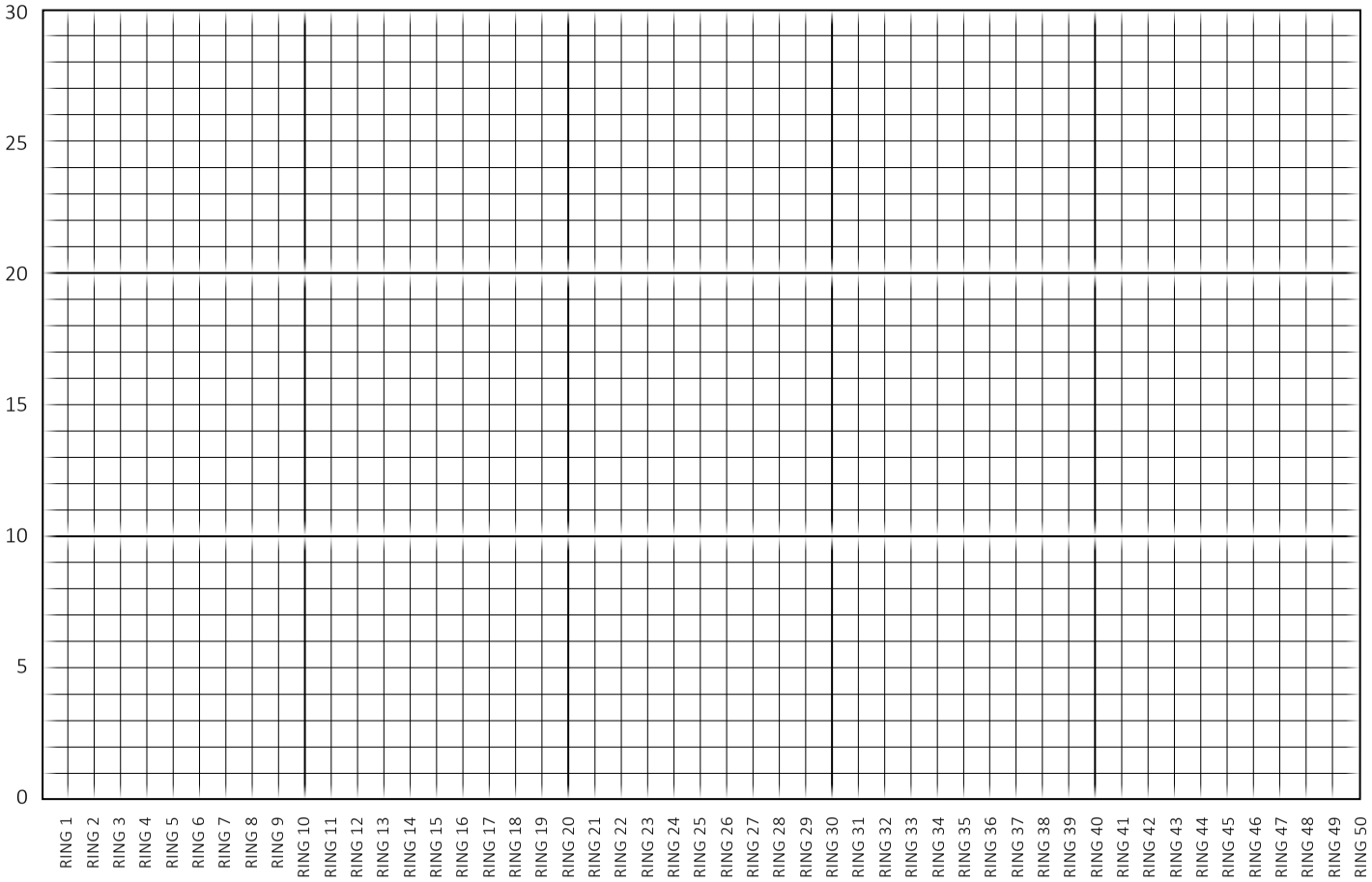
Sequence Table

Ring 1	5	Ring 11	17	Ring 21	21	Ring 31	7	Ring 41	11
Ring 2	10	Ring 12	14	Ring 22	15	Ring 32	15	Ring 42	13
Ring 3	5	Ring 13	20	Ring 23	10	Ring 33	22	Ring 43	10
Ring 4	15	Ring 14	11	Ring 24	5	Ring 34	26	Ring 44	8
Ring 5	13	Ring 15	16	Ring 25	10	Ring 35	12	Ring 45	20
Ring 6	10	Ring 16	20	Ring 26	12	Ring 36	22	Ring 46	10
Ring 7	9	Ring 17	25	Ring 27	15	Ring 37	10	Ring 47	15
Ring 8	13	Ring 18	22	Ring 28	10	Ring 38	9	Ring 48	12
Ring 9	12	Ring 19	20	Ring 29	13	Ring 39	8	Ring 49	10
Ring 10	11	Ring 20	17	Ring 30	9	Ring 40	15	Ring 50	7

Measurements in mm

Sequence graph recording sheet

R4



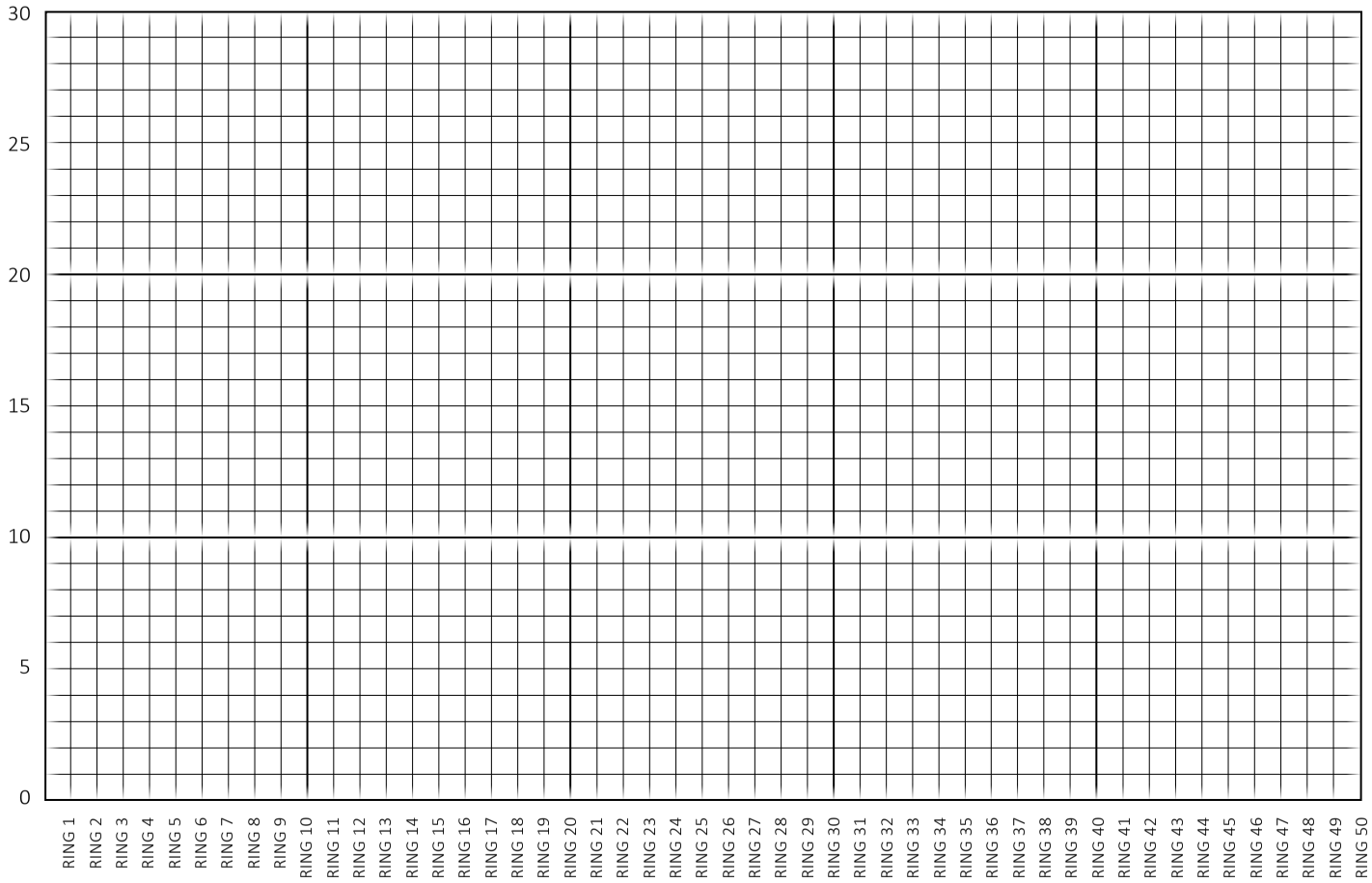
Sequence Table

Ring 1	12	Ring 11	20	Ring 21	11	Ring 31	25	Ring 41	10
Ring 2	22	Ring 12	10	Ring 22	15	Ring 32	19	Ring 42	18
Ring 3	10	Ring 13	15	Ring 23	20	Ring 33	22	Ring 43	21
Ring 4	9	Ring 14	12	Ring 24	7	Ring 34	16	Ring 44	10
Ring 5	8	Ring 15	10	Ring 25	12	Ring 35	15	Ring 45	5
Ring 6	15	Ring 16	7	Ring 26	7	Ring 36	10	Ring 46	23
Ring 7	11	Ring 17	5	Ring 27	10	Ring 37	8	Ring 47	26
Ring 8	13	Ring 18	7	Ring 28	8	Ring 38	12	Ring 48	29
Ring 9	10	Ring 19	8	Ring 29	15	Ring 39	10	Ring 49	23
Ring 10	8	Ring 20	9	Ring 30	18	Ring 40	15	Ring 50	29

Measurements in mm

Sequence graph recording sheet

I1



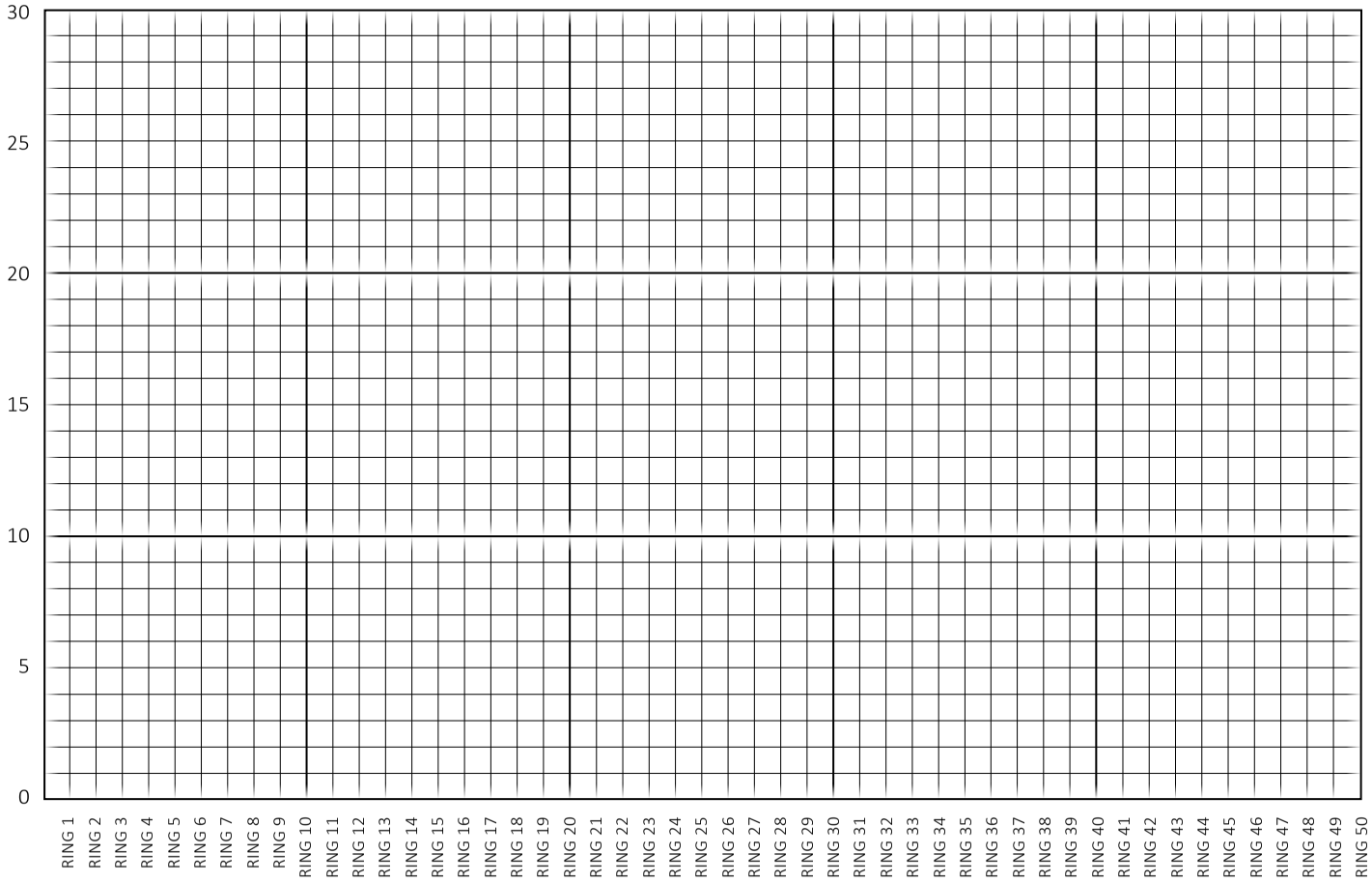
Sequence Table

Ring 1	15	Ring 11	5	Ring 21	25	Ring 31	28	Ring 41	25
Ring 2	10	Ring 12	23	Ring 22	15	Ring 32	23	Ring 42	15
Ring 3	8	Ring 13	26	Ring 23	27	Ring 33	27	Ring 43	27
Ring 4	12	Ring 14	29	Ring 24	24	Ring 34	20	Ring 44	23
Ring 5	10	Ring 15	23	Ring 25	22	Ring 35	22	Ring 45	24
Ring 6	15	Ring 16	29	Ring 26	20	Ring 36	20	Ring 46	12
Ring 7	10	Ring 17	20	Ring 27	19	Ring 37	17	Ring 47	10
Ring 8	18	Ring 18	28	Ring 28	16	Ring 38	20	Ring 48	13
Ring 9	21	Ring 19	24	Ring 29	12	Ring 39	23	Ring 49	8
Ring 10	10	Ring 20	28	Ring 30	25	Ring 40	20	Ring 50	16

Measurements in mm

Sequence graph recording sheet

N3



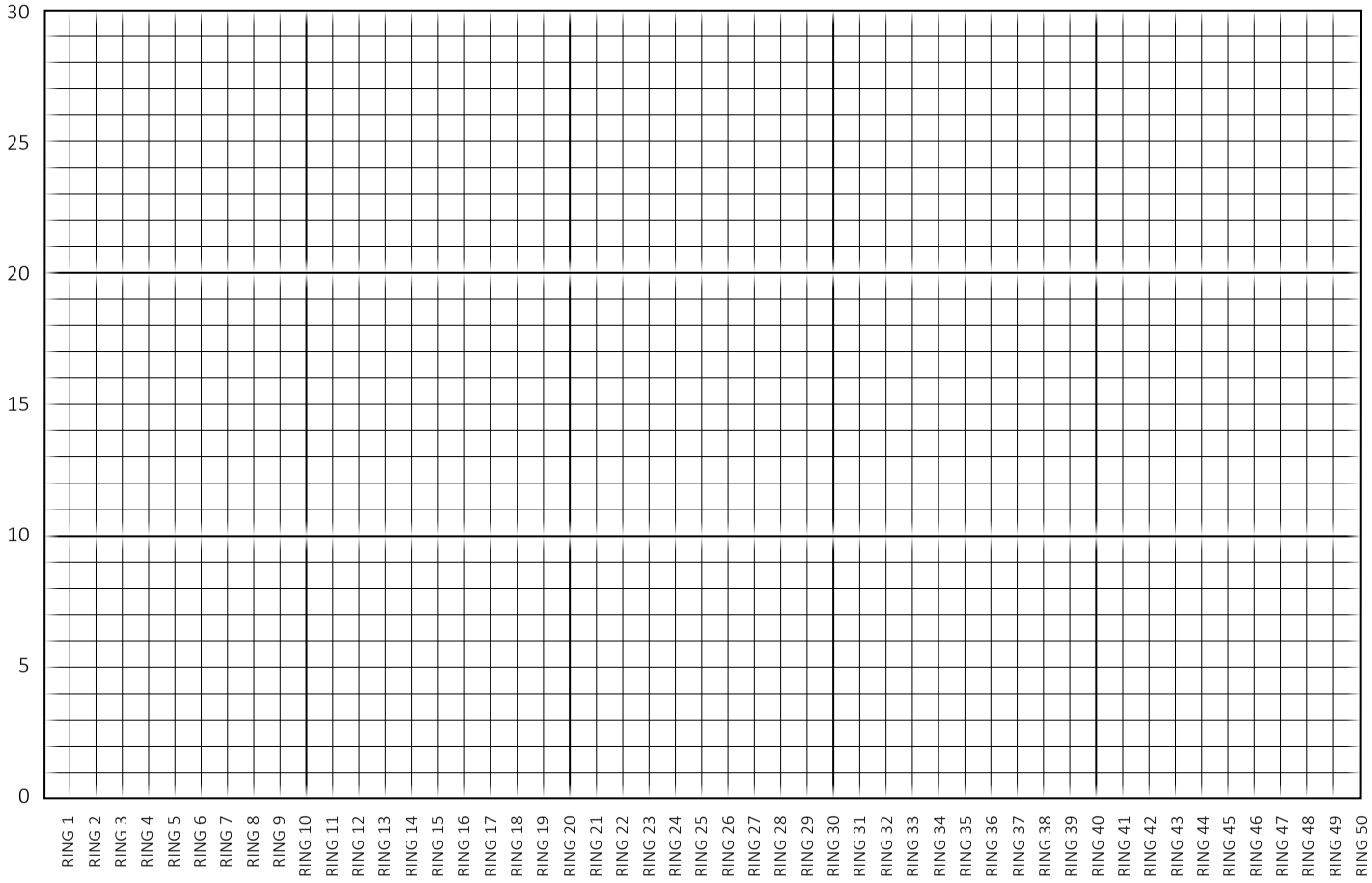
Sequence Table

Ring 1	22	Ring 11	24	Ring 21	15	Ring 31	21	Ring 41	15
Ring 2	20	Ring 12	12	Ring 22	20	Ring 32	5	Ring 42	18
Ring 3	17	Ring 13	10	Ring 23	21	Ring 33	11	Ring 43	13
Ring 4	20	Ring 14	13	Ring 24	25	Ring 34	8	Ring 44	18
Ring 5	23	Ring 15	8	Ring 25	18	Ring 35	12	Ring 45	15
Ring 6	20	Ring 16	16	Ring 26	16	Ring 36	16	Ring 46	20
Ring 7	25	Ring 17	13	Ring 27	18	Ring 37	13	Ring 47	18
Ring 8	15	Ring 18	5	Ring 28	12	Ring 38	25	Ring 48	13
Ring 9	27	Ring 19	12	Ring 29	15	Ring 39	17	Ring 49	21
Ring 10	23	Ring 20	10	Ring 30	10	Ring 40	27	Ring 50	20

Measurements in mm

Sequence graph recording sheet

G2



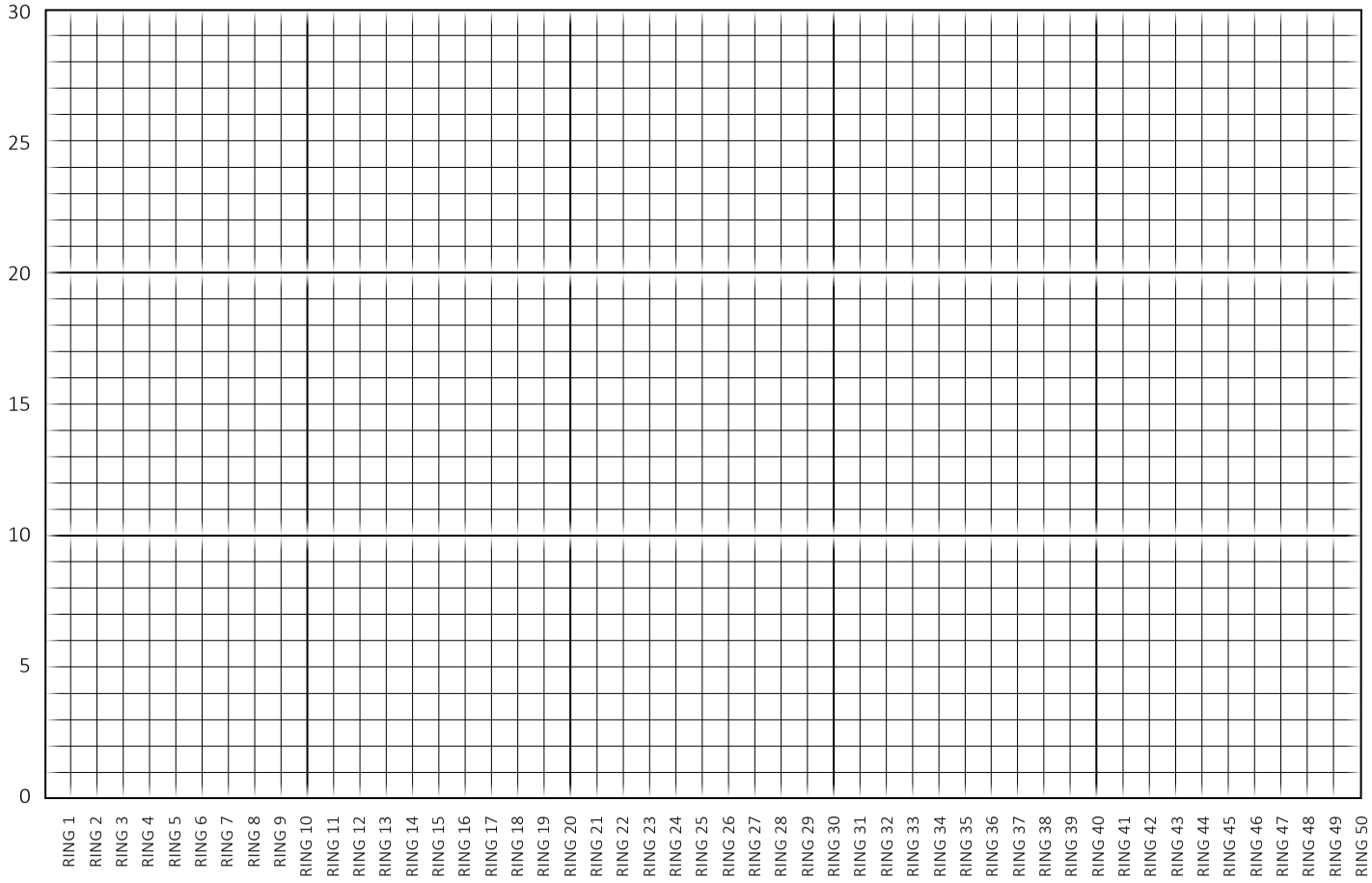
Sequence Table

Ring 1	12	Ring 11	15	Ring 21	22	Ring 31	20	Ring 41	10
Ring 2	16	Ring 12	20	Ring 22	10	Ring 32	18	Ring 42	6
Ring 3	13	Ring 13	18	Ring 23	9	Ring 33	23	Ring 43	15
Ring 4	25	Ring 14	13	Ring 24	5	Ring 34	20	Ring 44	16
Ring 5	17	Ring 15	21	Ring 25	12	Ring 35	20	Ring 45	18
Ring 6	27	Ring 16	20	Ring 26	9	Ring 36	20	Ring 46	26
Ring 7	15	Ring 17	18	Ring 27	11	Ring 37	22	Ring 47	23
Ring 8	18	Ring 18	18	Ring 28	19	Ring 38	17	Ring 48	27
Ring 9	13	Ring 19	18	Ring 29	20	Ring 39	15	Ring 49	22
Ring 10	18	Ring 20	14	Ring 30	25	Ring 40	14	Ring 50	24

Measurements in mm

Sequence graph recording sheet

D3



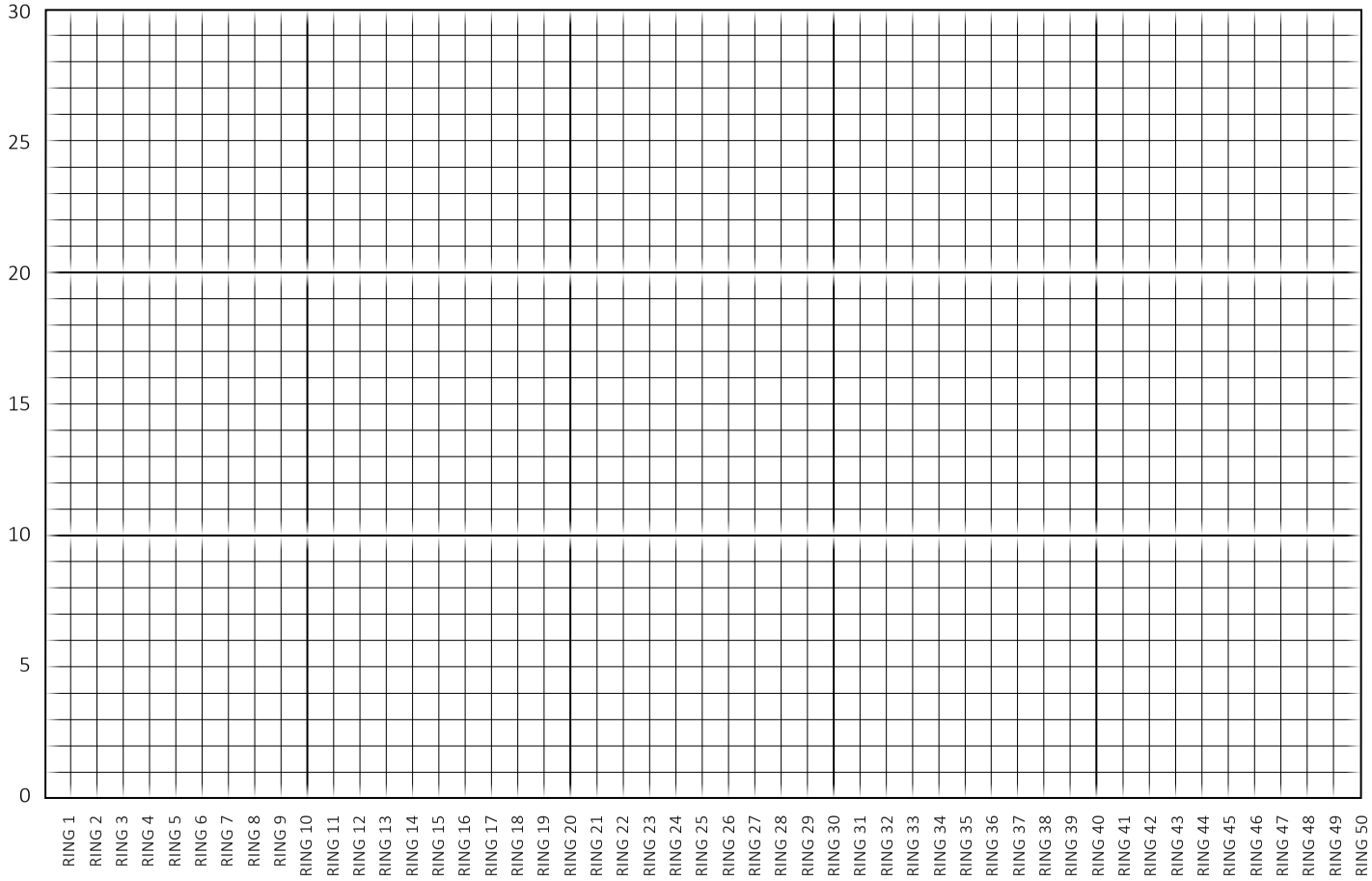
Sequence Table

Ring 1	20	Ring 11	18	Ring 21	8	Ring 31	19	Ring 41	8
Ring 2	20	Ring 12	26	Ring 22	10	Ring 32	15	Ring 42	5
Ring 3	22	Ring 13	23	Ring 23	11	Ring 33	18	Ring 43	3
Ring 4	17	Ring 14	27	Ring 24	12	Ring 34	16	Ring 44	10
Ring 5	15	Ring 15	22	Ring 25	17	Ring 35	20	Ring 45	10
Ring 6	14	Ring 16	24	Ring 26	12	Ring 36	14	Ring 46	10
Ring 7	10	Ring 17	13	Ring 27	11	Ring 37	10	Ring 47	10
Ring 8	6	Ring 18	17	Ring 28	10	Ring 38	14	Ring 48	10
Ring 9	15	Ring 19	12	Ring 29	6	Ring 39	8	Ring 49	13
Ring 10	16	Ring 20	15	Ring 30	11	Ring 40	13	Ring 50	7

Measurements in mm

Sequence graph recording sheet

A1



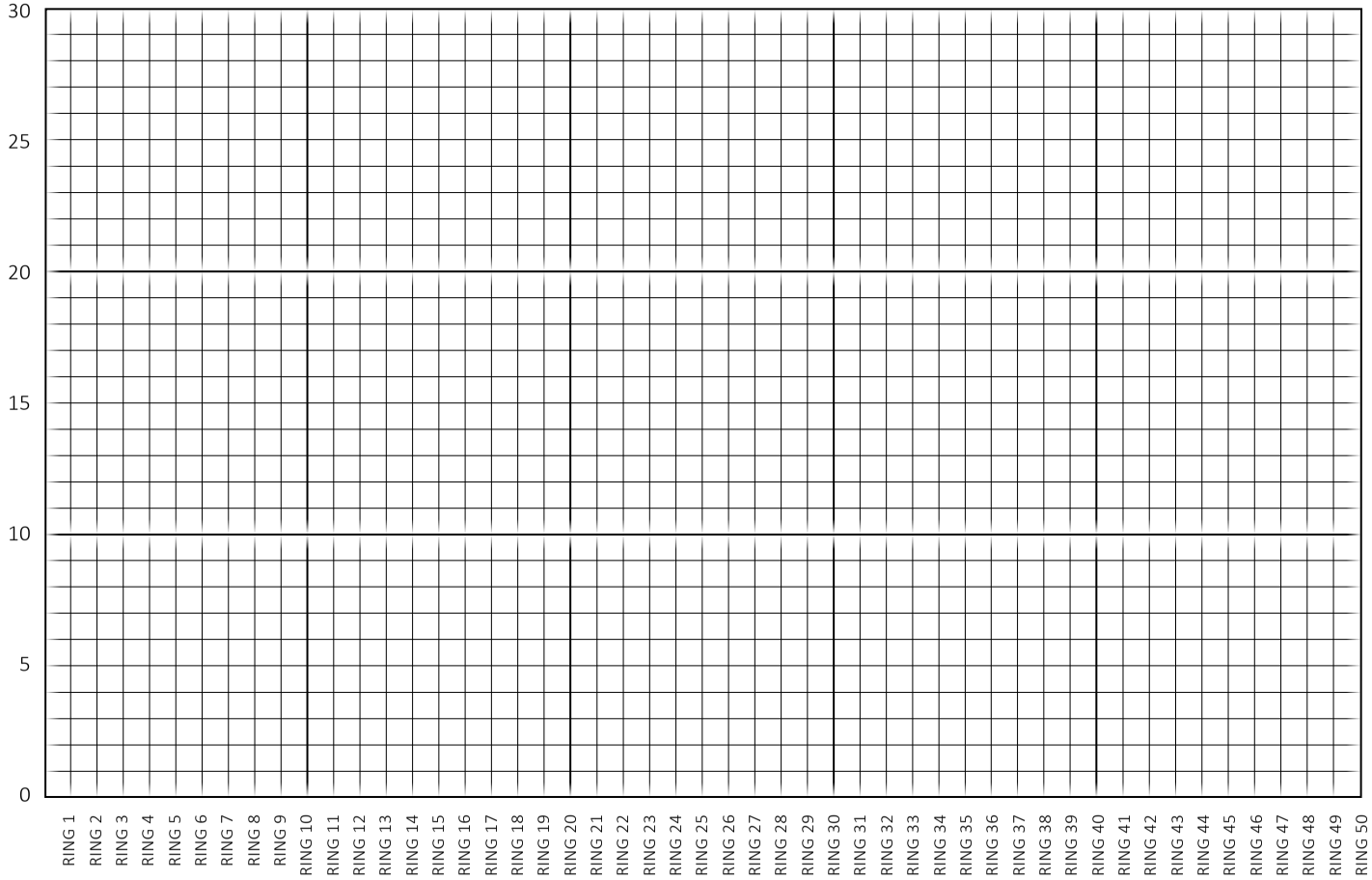
Sequence Table

Ring 1	20	Ring 11	10	Ring 21	8	Ring 31	12	Ring 41	6
Ring 2	14	Ring 12	10	Ring 22	10	Ring 32	5	Ring 42	12
Ring 3	10	Ring 13	10	Ring 23	11	Ring 33	13	Ring 43	14
Ring 4	14	Ring 14	10	Ring 24	13	Ring 34	14	Ring 44	10
Ring 5	8	Ring 15	13	Ring 25	16	Ring 35	15	Ring 45	20
Ring 6	13	Ring 16	7	Ring 26	8	Ring 36	17	Ring 46	13
Ring 7	8	Ring 17	11	Ring 27	18	Ring 37	10	Ring 47	20
Ring 8	5	Ring 18	15	Ring 28	13	Ring 38	13	Ring 48	14
Ring 9	3	Ring 19	11	Ring 29	14	Ring 39	8	Ring 49	22
Ring 10	10	Ring 20	13	Ring 30	15	Ring 40	10	Ring 50	15

Measurements in mm

Sequence graph recording sheet

T2



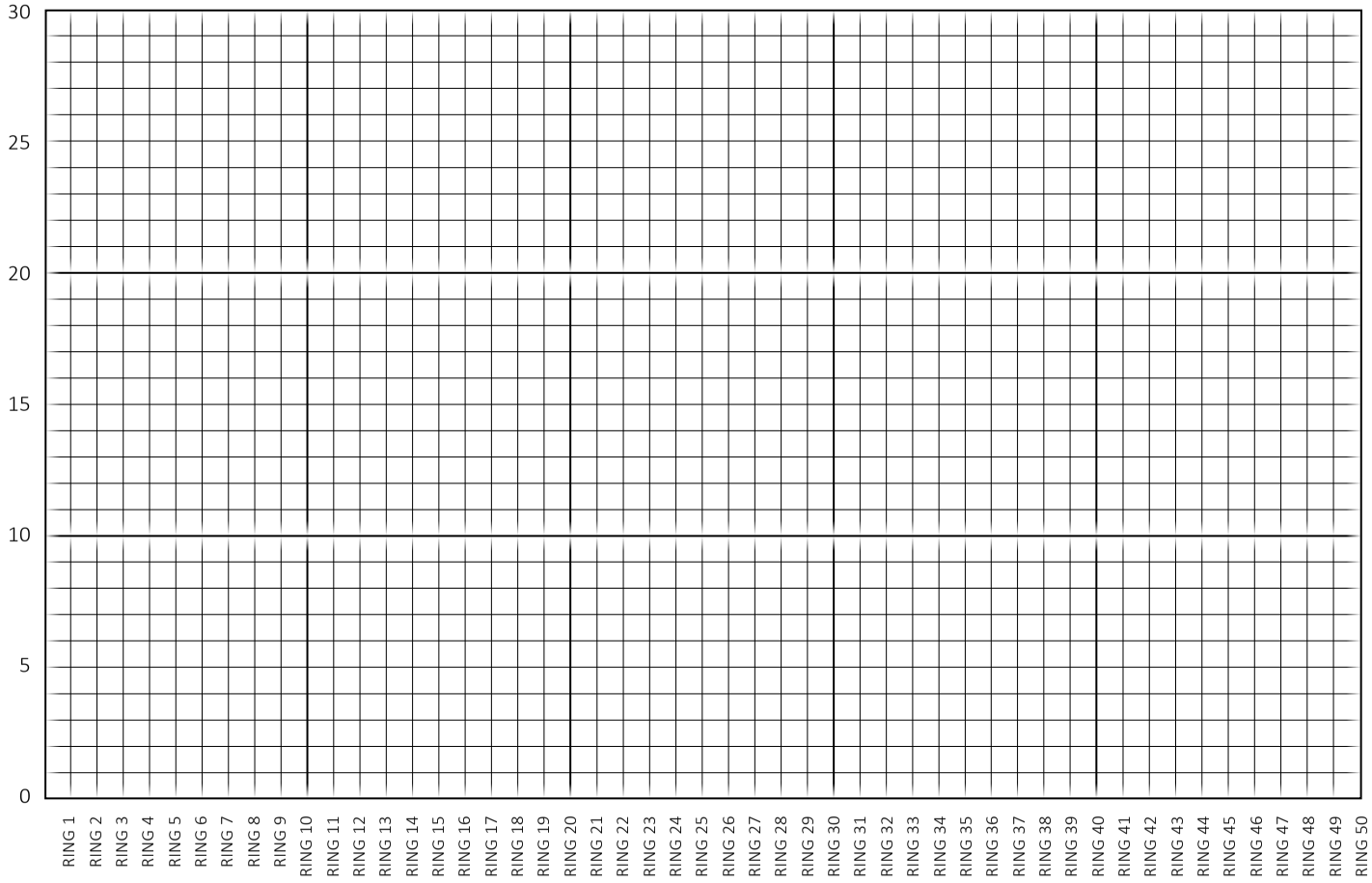
Sequence Table

Ring 1	15	Ring 11	20	Ring 21	12	Ring 31	20	Ring 41	10
Ring 2	17	Ring 12	13	Ring 22	8	Ring 32	14	Ring 42	8
Ring 3	10	Ring 13	20	Ring 23	13	Ring 33	11	Ring 43	11
Ring 4	13	Ring 14	14	Ring 24	12	Ring 34	13	Ring 44	10
Ring 5	8	Ring 15	22	Ring 25	20	Ring 35	10	Ring 45	10
Ring 6	10	Ring 16	15	Ring 26	12	Ring 36	13	Ring 46	23
Ring 7	6	Ring 17	12	Ring 27	25	Ring 37	8	Ring 47	5
Ring 8	12	Ring 18	15	Ring 28	17	Ring 38	13	Ring 48	14
Ring 9	14	Ring 19	12	Ring 29	15	Ring 39	10	Ring 49	11
Ring 10	10	Ring 20	16	Ring 30	9	Ring 40	7	Ring 50	23

Measurements in mm

Sequence graph recording sheet

I2



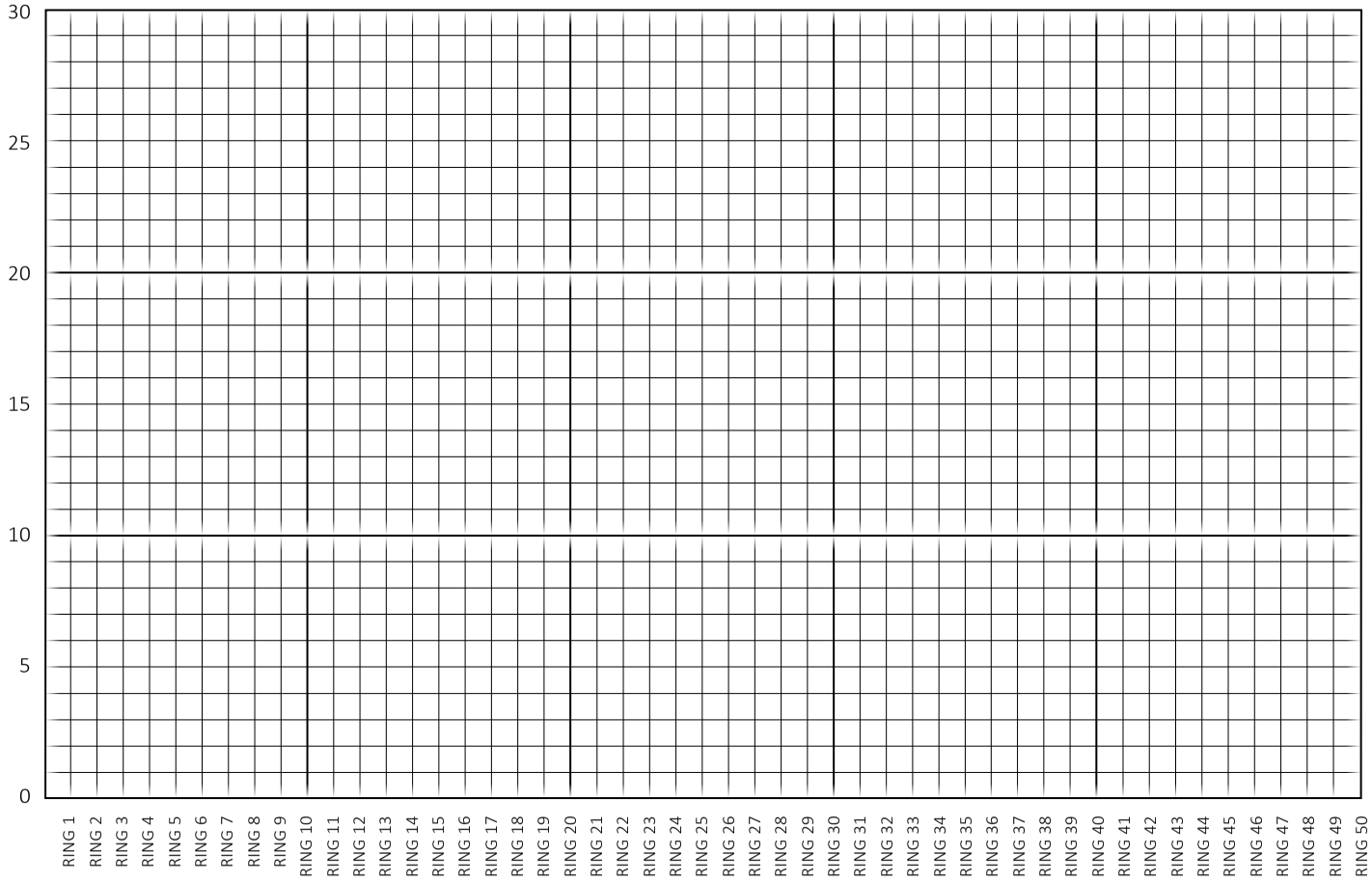
Sequence Table

Ring 1	10	Ring 11	10	Ring 21	17	Ring 31	15	Ring 41	8
Ring 2	13	Ring 12	23	Ring 22	18	Ring 32	10	Ring 42	10
Ring 3	8	Ring 13	5	Ring 23	20	Ring 33	8	Ring 43	11
Ring 4	13	Ring 14	14	Ring 24	28	Ring 34	2	Ring 44	13
Ring 5	10	Ring 15	11	Ring 25	15	Ring 35	25	Ring 45	15
Ring 6	7	Ring 16	23	Ring 26	22	Ring 36	22	Ring 46	20
Ring 7	10	Ring 17	22	Ring 27	10	Ring 37	18	Ring 47	18
Ring 8	8	Ring 18	21	Ring 28	8	Ring 38	15	Ring 48	25
Ring 9	11	Ring 19	5	Ring 29	7	Ring 39	13	Ring 49	22
Ring 10	10	Ring 20	15	Ring 30	5	Ring 40	10	Ring 50	29

Measurements in mm

Sequence graph recording sheet

N4



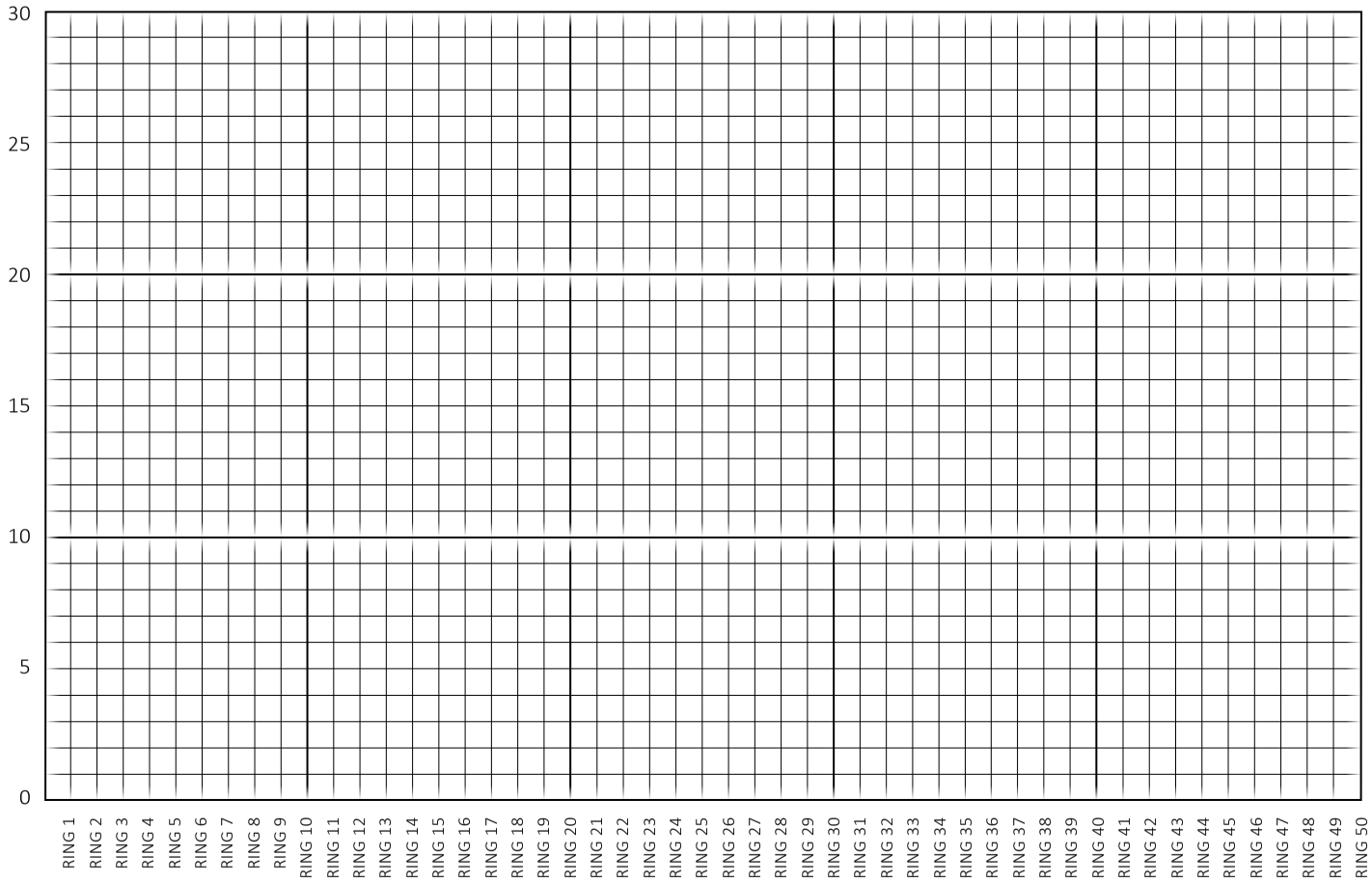
Sequence Table

Ring 1	25	Ring 11	15	Ring 21	15	Ring 31	10	Ring 41	5
Ring 2	22	Ring 12	20	Ring 22	17	Ring 32	7	Ring 42	12
Ring 3	18	Ring 13	18	Ring 23	18	Ring 33	15	Ring 43	10
Ring 4	15	Ring 14	25	Ring 24	11	Ring 34	10	Ring 44	21
Ring 5	13	Ring 15	22	Ring 25	15	Ring 35	15	Ring 45	25
Ring 6	10	Ring 16	29	Ring 26	20	Ring 36	8	Ring 46	18
Ring 7	8	Ring 17	20	Ring 27	10	Ring 37	20	Ring 47	23
Ring 8	10	Ring 18	24	Ring 28	15	Ring 38	10	Ring 48	16
Ring 9	11	Ring 19	18	Ring 29	11	Ring 39	3	Ring 49	20
Ring 10	13	Ring 20	16	Ring 30	7	Ring 40	10	Ring 50	18

Measurements in mm

Sequence graph recording sheet

G3



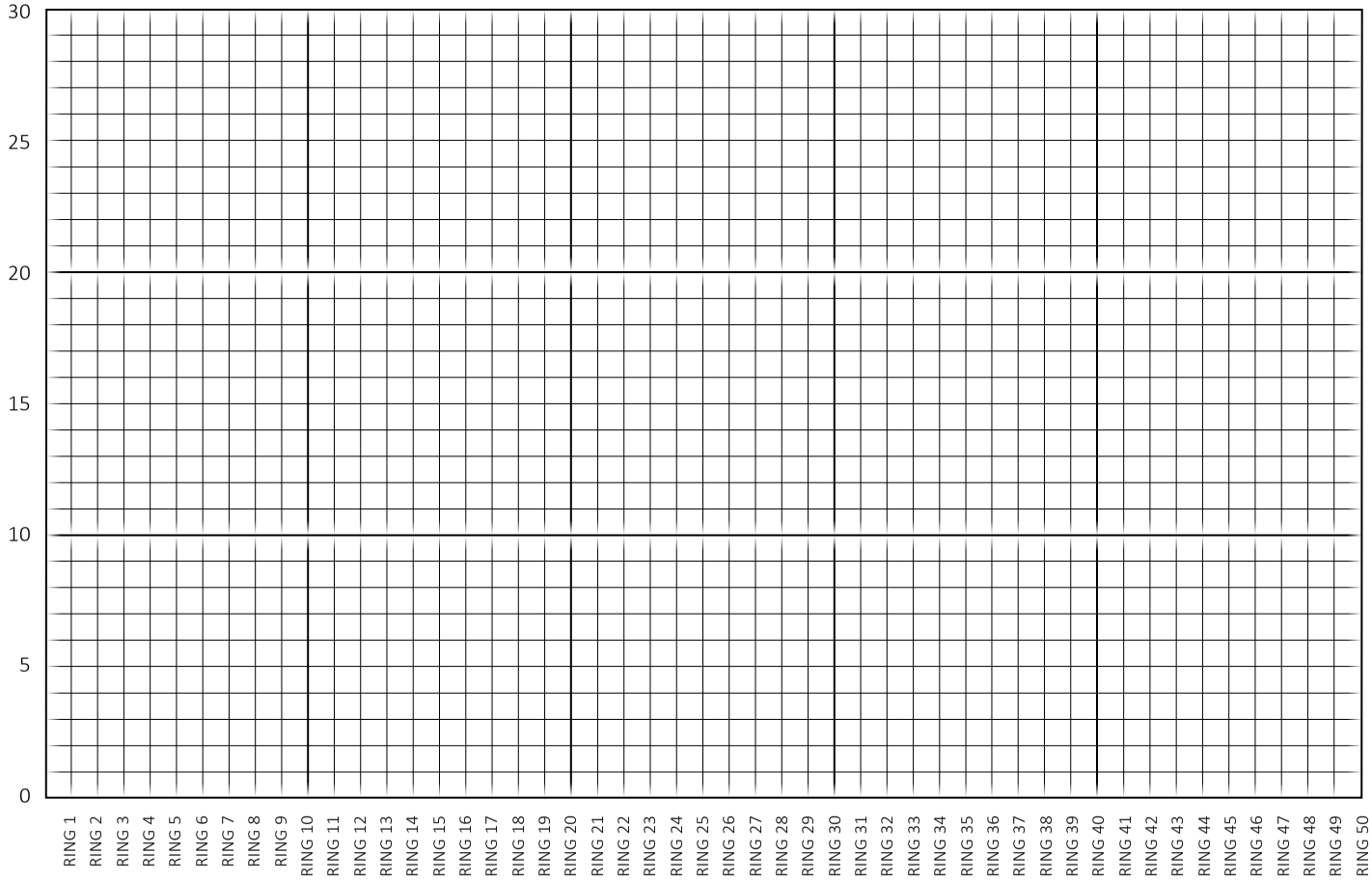
Sequence Table

Ring 1	15	Ring 11	25	Ring 21	13	Ring 31	20	Ring 41	15
Ring 2	8	Ring 12	18	Ring 22	17	Ring 32	25	Ring 42	19
Ring 3	20	Ring 13	23	Ring 23	15	Ring 33	22	Ring 43	15
Ring 4	10	Ring 14	16	Ring 24	25	Ring 34	20	Ring 44	21
Ring 5	3	Ring 15	20	Ring 25	28	Ring 35	18	Ring 45	19
Ring 6	10	Ring 16	18	Ring 26	24	Ring 36	25	Ring 46	10
Ring 7	5	Ring 17	21	Ring 27	30	Ring 37	21	Ring 47	15
Ring 8	12	Ring 18	18	Ring 28	23	Ring 38	25	Ring 48	9
Ring 9	10	Ring 19	22	Ring 29	19	Ring 39	20	Ring 49	10
Ring 10	21	Ring 20	17	Ring 30	23	Ring 40	23	Ring 50	18

Measurements in mm

Sequence graph recording sheet

Bridge Foundation Pile



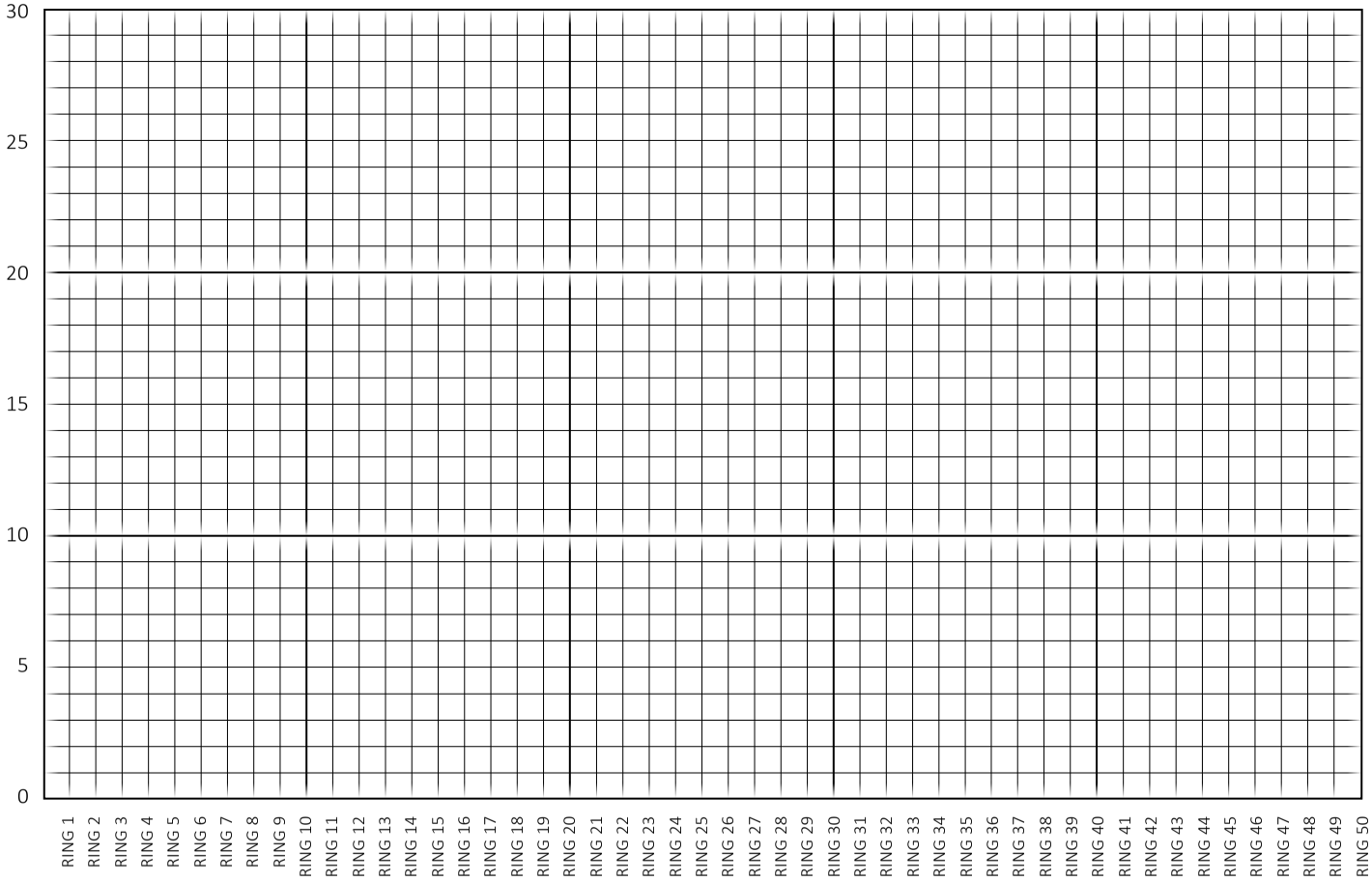
Sequence Table

Ring 7	14	Ring 17	15	Ring 27	5	Ring 37	13		
Ring 8	17	Ring 18	16	Ring 28	12	Ring 38	15		
Ring 9	16	Ring 19	15	Ring 29	10	Ring 39	16		
Ring 10	20	Ring 20	14	Ring 30	17	Ring 40	18		
Ring 11	18	Ring 21	17	Ring 31	19	Ring 41	10		
Ring 12	25	Ring 22	10	Ring 32	16				
Ring 13	20	Ring 23	24	Ring 33	21				
Ring 14	15	Ring 24	26	Ring 34	16				
Ring 15	13	Ring 25	25	Ring 35	17				
Ring 16	17	Ring 26	16	Ring 36	18				

Measurements in mm

Sequence graph recording sheet

Rafter



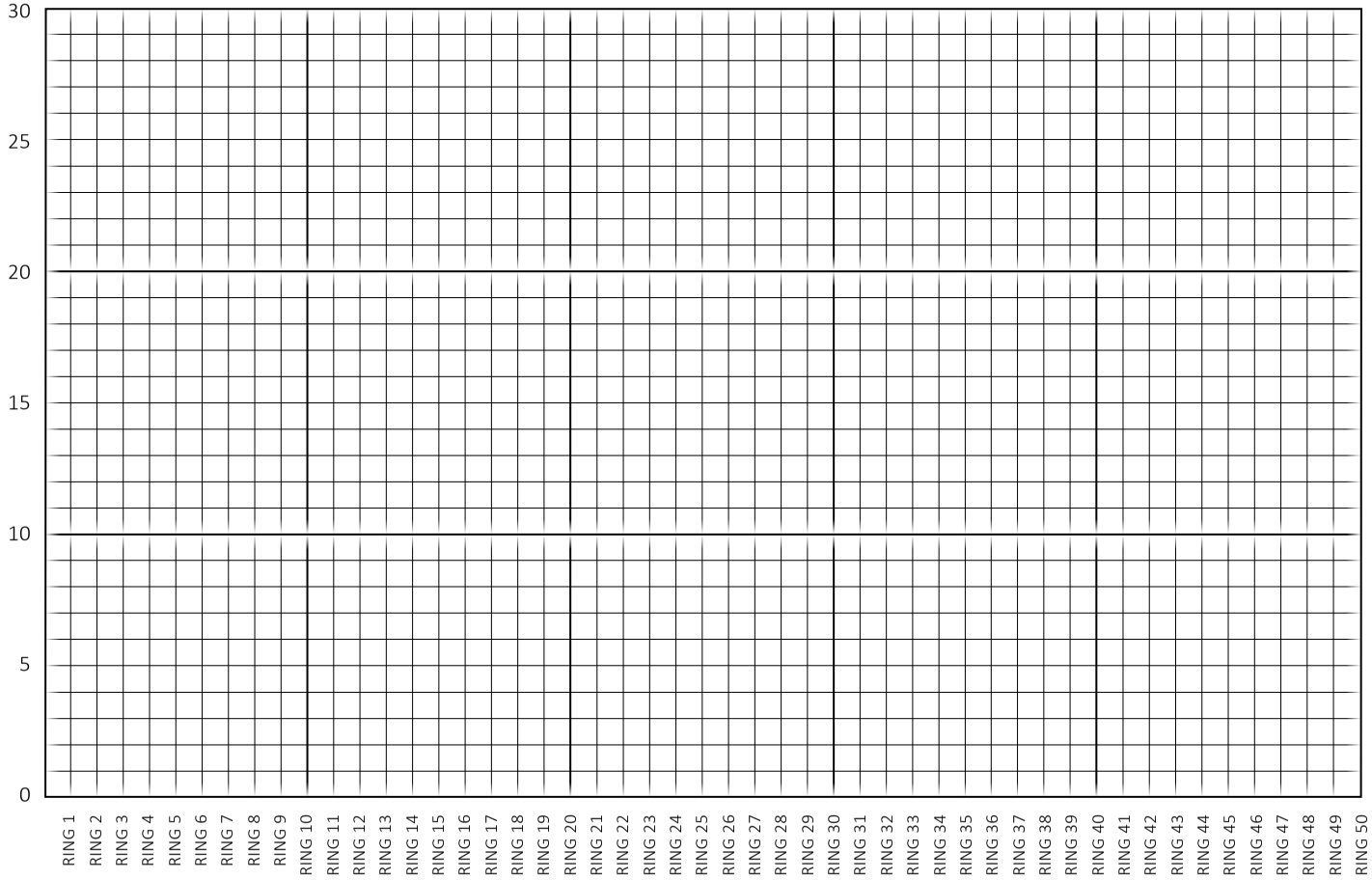
Sequence Table

Ring 16	15	Ring 26	20	Ring 36	13	Ring 46	15		
Ring 17	21	Ring 27	23	Ring 37	15	Ring 47	5		
Ring 18	15	Ring 28	25	Ring 38	20	Ring 48	11		
Ring 19	10	Ring 29	23	Ring 39	17	Ring 49	7		
Ring 20	17	Ring 30	15	Ring 40	24	Ring 50	10		
Ring 21	15	Ring 31	12	Ring 41	20				
Ring 22	12	Ring 32	11	Ring 42	23				
Ring 23	15	Ring 33	10	Ring 43	19				
Ring 24	7	Ring 34	6	Ring 44	23				
Ring 25	12	Ring 35	12	Ring 45	19				

Measurements in mm

Sequence graph recording sheet

Floorboard



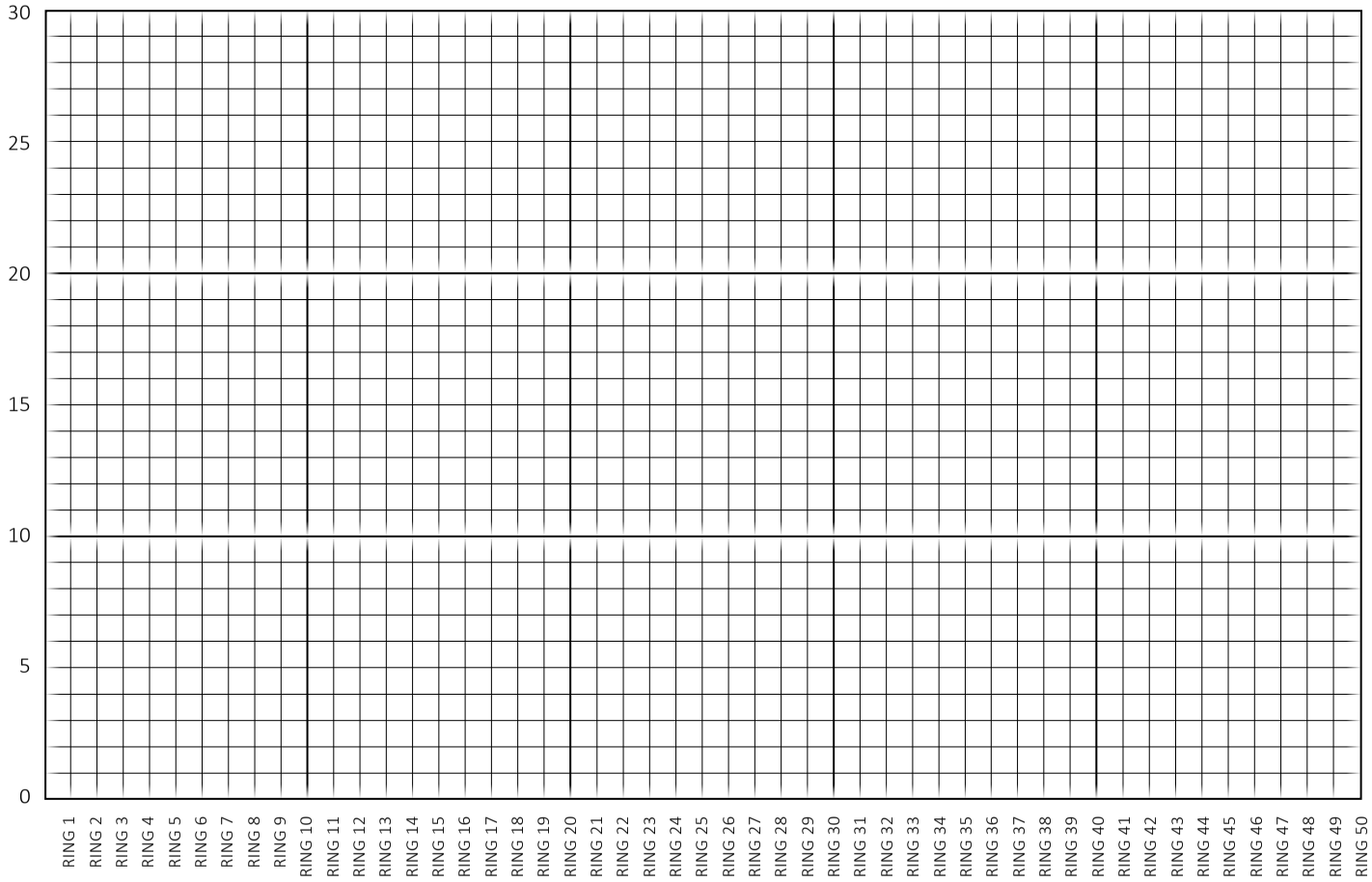
Sequence Table

Ring 8	15	Ring 18	5	Ring 28	12	Ring 38	25		
Ring 9	27	Ring 19	12	Ring 29	15	Ring 39	17		
Ring 10	23	Ring 20	10	Ring 30	10	Ring 40	27		
Ring 11	24	Ring 21	15	Ring 31	21	Ring 41	15		
Ring 12	12	Ring 22	20	Ring 32	5	Ring 42	18		
Ring 13	10	Ring 23	21	Ring 33	11				
Ring 14	13	Ring 24	25	Ring 34	8				
Ring 15	8	Ring 25	18	Ring 35	12				
Ring 16	16	Ring 26	16	Ring 36	16				
Ring 17	13	Ring 27	18	Ring 37	13				

Measurements in mm

Sequence graph recording sheet

Ceiling Joist



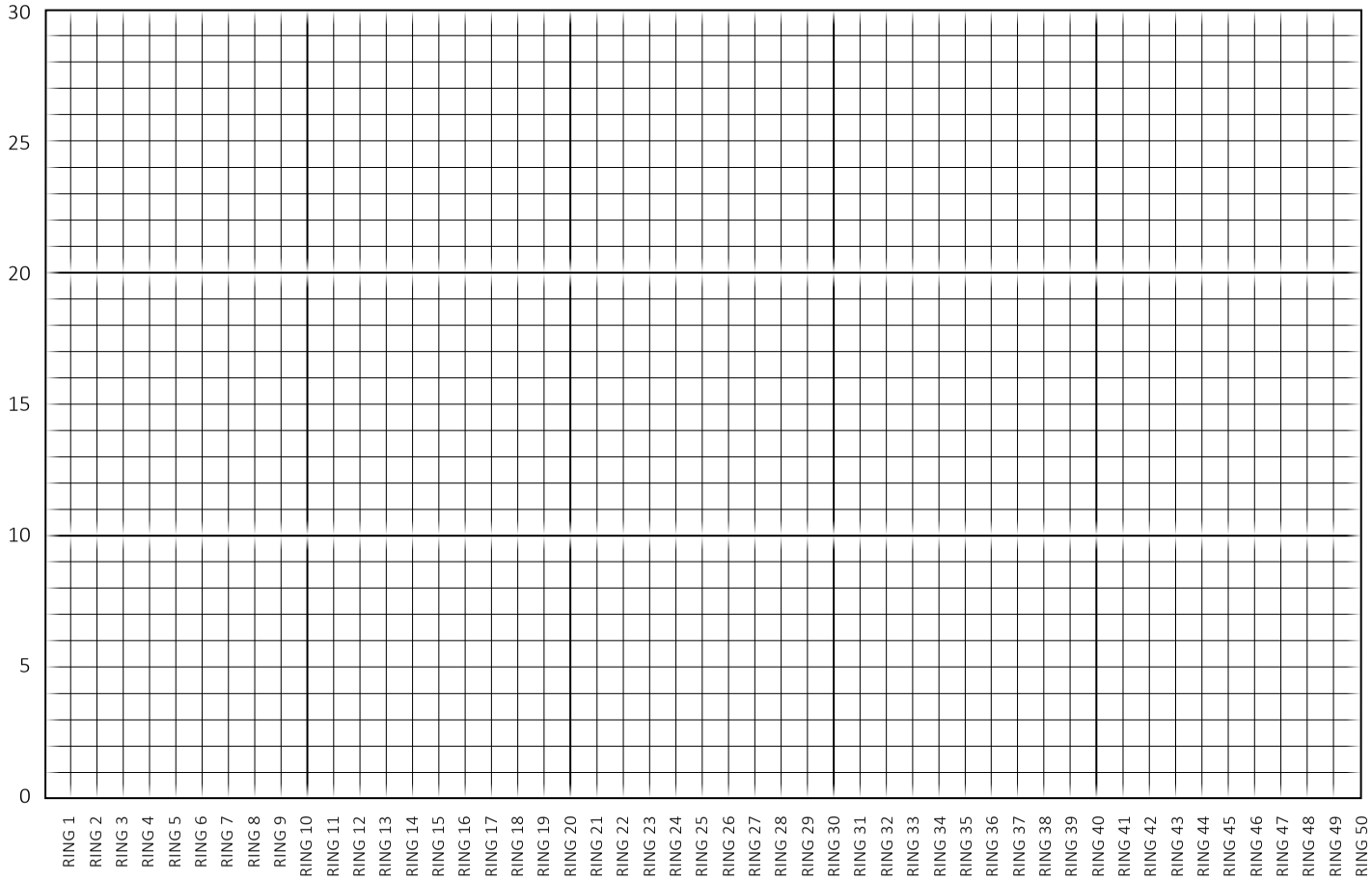
Sequence Table

Ring 8	12	Ring 18	15	Ring 28	17	Ring 38	13		
Ring 9	14	Ring 19	12	Ring 29	15	Ring 39	10		
Ring 10	10	Ring 20	16	Ring 30	9	Ring 40	7		
Ring 11	20	Ring 21	12	Ring 31	20	Ring 41	10		
Ring 12	13	Ring 22	8	Ring 32	14	Ring 42	8		
Ring 13	20	Ring 23	13	Ring 33	11				
Ring 14	14	Ring 24	12	Ring 34	13				
Ring 15	22	Ring 25	20	Ring 35	10				
Ring 16	15	Ring 26	12	Ring 36	13				
Ring 17	12	Ring 27	25	Ring 37	8				

Measurements in mm

Sequence graph recording sheet

Wainscott Panelling



Sequence Table

Ring 10	10	Ring 20	15	Ring 30	5	Ring 40	10		
Ring 11	10	Ring 21	17	Ring 31	15	Ring 41	8		
Ring 12	23	Ring 22	18	Ring 32	10	Ring 42	10		
Ring 13	5	Ring 23	20	Ring 33	8	Ring 43	11		
Ring 14	14	Ring 24	28	Ring 34	2	Ring 44	13		
Ring 15	11	Ring 25	15	Ring 35	25				
Ring 16	23	Ring 26	22	Ring 36	22				
Ring 17	22	Ring 27	10	Ring 37	18				
Ring 18	21	Ring 28	8	Ring 38	15				
Ring 19	5	Ring 29	7	Ring 39	13				

Measurements in mm

References

Archaeology: the widening debate
(Barry Cunliffe, Wendy Davies and Colin Renfrew eds 2002)

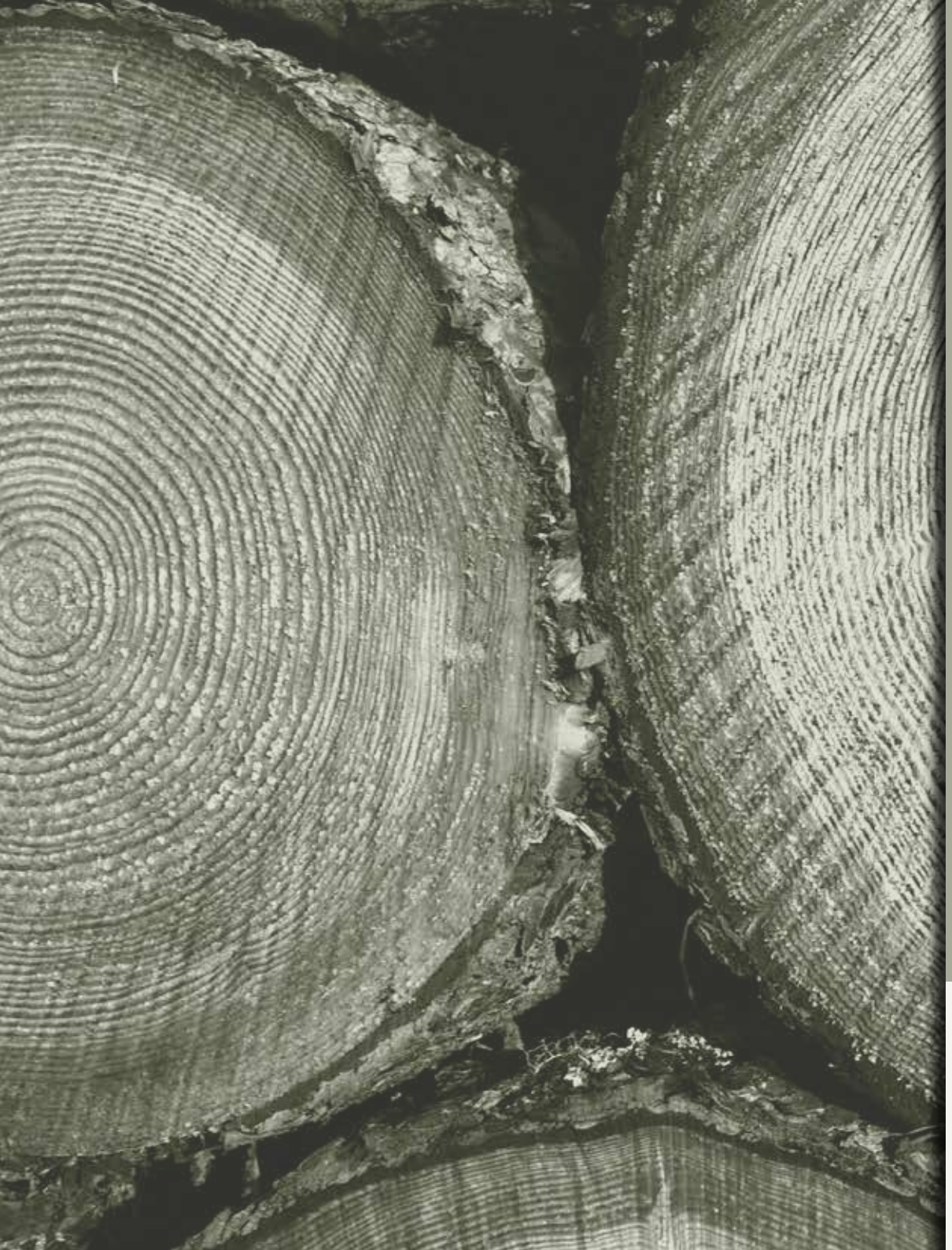
Outdoor Archaeological Learning
(Forestry Commission Scotland 2017)

Tree-ring dating and archaeology
(Mike Baillie 1982)

The South East Scotland Oak Dendrochronology Project

The South East Scotland Oak Dendrochronology (SESOD) project is developing the first long oak reference chronology for this region. Native timbers are underrepresented in the Scottish tree ring record compared to more readily identified imports and South East Scotland is a particular gap. SESOD is led by Dr Coralie Mills and is funded by Historic Environment Scotland's Archaeology Programme.

Find out more at www.dendrochronicle.co.uk



About the authors

Marcia Cook

Marcia Cook has been involved in archaeological projects across Scotland, Europe, the Mediterranean and the Middle East. Her current interests lie in the design and delivery of archaeological education and its wider role in community engagement, supporting individual learners at all levels.

Coralie Mills

Coralie Mills is a dendrochronologist and woodland heritage specialist with a long career in Scottish archaeology. She is interested in historic wooded landscapes and the use of native Scottish woods in the medieval and post-medieval periods. She runs her own consultancy *Dendrochronicle* and is an Honorary Fellow of the University of St Andrews.

Jennifer Thoms

Jennifer Thoms combines her love of Scottish archaeology and her love of words by editing Archaeology Scotland's annual journal *Discovery and Excavation in Scotland*. She has a particular interest in how people interacted with their environment in the past, and enjoys using archaeology in learning and teaching.

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This resource will be of interest to teachers, archaeological educators and youth group leaders – and to anyone with an interest in the presentation and interpretation of archaeological science.

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