Experimental Archaeology and Neolithic Architecture

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Between Design and Construction

By

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For Carole and Neil

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ACKNOWLEDGEMENTS

There is an old Chinese proverb which states that "The journey of a thousand miles begins with the first step." My first step towards publishing this thesis began almost ten years ago and it seem appropriate for me now to thank those who academically guided me along the way – albeit a "little bit too late."

My first appreciation is to Dr Jane Moore who helped me right from the start of my studies with achieving a Higher Education qualification. Not only did Jane help me to successfully finish a Diploma in Archaeology with the University of Liverpool's Continuing Education but she also put me in touch with the late Dr Joan Taylor who was then actively head of British and European Archaeology at the main University. For sure, I cannot express in words my appreciation for Joan's guidance to further my journey. It was both her encouragement and mentoring that opened the way towards completing my next "big step forward" – a Masters in Archaeology.

At that time I was still holding down full time employment, so the part time Masters programme was a welcome break from working in a bank, and I thoroughly enjoyed the learning experience; and it was during these studies that I came under the radar of my next mentors, Dr Matthew Fitzjohn and Dr Duncan Garrow. Certainly, I could not have marched the next steps forward towards a doctorate without their support, insight and wisdom. I should also express gratitude to Dr Phil Freeman and Dr Joshua Pollard for their additional advice during the final days of the PhD.

From a non-academic appreciation, I must also thank my family and friends for their support throughout this journey. To Carole and Neil for their companionship during those field trips amongst the best and worst of the British weather. And to my friends Brian Coggins and Les Johnson for their contributions towards the preparations of this book. And, in the case of the latter, I also thank Les once again for providing the several sketches which appear in this book.

Finally, this "journey" has not just been about achieving academic qualifications; it has also been one of self-discovery and personal transformation and whilst a thousand miles might seem a long way to walk

just to find one's inner self: when every step is enjoyable then somehow both the distance and time involved becomes insignificant.

CHAPTER ONE

INTRODUCTION

Our understanding of the construction processes involved before any British prehistoric structure was physically built, that is from the moment when its design had been conceived in someone's mind up to the point when its construction commenced, needs further investigation.

During the British Neolithic, circa 4000-2500 BC, we witness the building of numerous ceremonial, domestic and funerary structures which dominated the prehistoric landscape. Providing an absolute total as to how many of them were built during this period is not possible. Undoubtedly, we could be looking at a figure in the thousands. And, if we accept the fact that the architectural form of these structures was so designed that their appearance visibly indicated the specific types of rituals or domestic usages that could be legitimately held there (Fleming 1973,189), then accordingly, their respective designs would have had to been well thought out: their architecture had to meet the visual and experiential expectations of the people. Overall, one is led to consider the possibility that any form of construction was the result of deliberate thinking and that the prehistoric builders were working to specific plans or blueprints in advance of any building work. Furthermore, moving from design to physical form required setting out, a technique which implied measuring of some description. But this is where we hit the major drawback to this assertion which the experimental archaeology described in this book attempts to tackle.

The British Neolithic communities were preliterate and they have certainly left behind no written records or sculptured, pictorial reliefs at any of their building works that could be interpreted as evidence of "architectural" blueprints or schematics. Nor, unlike the ancient Egyptian Pyramid builders, do we find surveyor marks or hints of measuring-notches scratched on the surfaces of those orthostats used to build their monuments. Worst still, archaeologists have yet to recover any material evidence of a system of British Neolithic numeracy that could have supported those techniques of both prehistoric surveying and setting out that must have been needed to build complex monuments like Stonehenge. In other words, we are left with the impression that the British prehistoric communities were illiterate and no better than "savage, ignorant builders" who could neither think nor count! Surely, this is not the case.

Without a doubt, British Archaeology does not have a happy relationship with the concept of deliberate design or intentional planning during the construction of Neolithic structures. Suggestions that there might have been "gifted individuals" building monuments using Megalithic Yards (Thom 1967) or Druid's Cubits (Stukeley 1740) are scorned upon. At best, academic attention towards such intellectual capabilities tends to be glossed over or, at worst, simply ignored. Thus, when it comes to analysing the construction techniques used with complex structures such as Stonehenge, then it is so much easier to avoid detailed discussion about surveying and "prehistoric metrology." In fact, avoid the subject is the best strategy. Otherwise, one will have the difficulty of both explaining and demonstrating the existence of systems of Neolithic numeracy across prehistoric Britain – for which there is no immediate material evidence.

Definitely, I do think that such a difficult subject should not be avoided and I will offer the results from my unique "rope experiments" whereby I have successfully reconstructed the ground plan designs of many Neolithic monuments using rudimentary methods (which I do believe the people could have used). For the secret of building any complex, prehistoric structure was to, firstly, mark out its definition on the ground and, secondly, build the monument from the ground upwards. Certainly, I am confident that my experiments can demonstrate how a preliterate society could have designed complex structures using their "preliterate mathematics." It could have all been accomplished by using lengths of rope, the sun's shadow at midday, finger reckoning plus gesturing with one's arms and hands. I refer to these procedures as my Occam's Razor Solution (i.e. the solution with the least number of variables to any complex problem makes it the most likely right choice). And, significantly, this Occam's Razor Solution is the key to understanding *Experimental Archaeology and Neolithic Architecture: Between Design and Construction*.

Before I begin presenting my hypothesis it would be prudent to give an overview of the forthcoming chapters, and I should also briefly discuss the nature of this book. Undoubtably, it is not about Neolithic archaeology per se. Rather it is specifically about experimental archaeology and the methods I use for reconstruction. Nor is this book solely a theoretical thesis. Notably, it provides a practical set of instructions for others to physically test my ideas. Of course, I realise that not every reader will have the opportunity to visit and survey all the monuments discussed here or set out their reconstructions on large, grassed areas. However, there is a way to test my ideas. That is, by studying the finger reckoning mathematics and the geometry associated with the design of those structures which I offer here. Indeed, by following my instructions one will be able to scale down my designs onto A4 paper, all from the comfort of one's own home.

Having set out my case, I will now proceed with a brief outline of what is to follow. This book is organized around seven chapters. The next chapter, Chapter Two, presents a literary review of the work of others. Whilst my experimental archaeology is unique, its methods, as a by-product, have identified themes about measuring and orientation which a number of other researchers have also covered and it would be appropriate to discuss their ideas. Although they have not actually proposed the same procedures of experimentation as I do, they have still touched upon the subject of intentional planning and it would be prudent to bring their thoughts into focus.

Chapter Three, Experimental Methods, describes the techniques I use for performing my experimental archaeology. Now, I have already discussed these methods in full elsewhere (Hill 2009d; Hill 2021a). So for now, a short summary in this chapter will suffice. Certainly, summarising these methods will provide me with that extra space to offer some new ideas which I have added to my Occam's Razor Solution. And such an opportunity allows me to raise the possibility that the Neolithic communities were "artistically" employing their hands and fingers for tasks other than counting when building their monuments. Indeed could there have been a sophisticated sign language in operation being used by the Neolithic builders during construction. Of course, I have no evidence for this but I will provide some simple "experimental gesturing techniques" for the reader to both consider and have fun trying them for themselves.

Chapter Four introduces the geometrical patterns which I have successfully used for the reconstruction of numerous Neolithic monuments. Although, there is one common starting point, there are three particular variations to its application. The first variation to be discussed in this chapter is a shape I refer to as the "Circle and Cross Geometry" and for the case study here, I will discuss a group of funerary monuments belonging to a common architectural style of long barrow known as the Cotswold Severn Group. These long barrows date to almost the start of the British Neolithic period, circa 3850-3500 BC. For special attention, I have selected the Capel Garmon long barrow (Denbighshire). I have chosen this particular monument not only because of its excellent extant remains but also its unrestricted access - hence the reader may be tempted to perform their own survey at this barrow. I shall begin the chapter by discussing these long barrows in general terms, including their respective archaeology and building methods, and then lead into a detailed explanation as to how the Circle and Cross Geometry can be used for the setting out of the Welsh barrow. After discussing that, I explain how this same technique works at two other long barrows i.e. Wayland's Smithy II (Oxfordshire) and Parc le Breos Cwm (Glamorgan), and end with a brief comment regarding two other tombs (the West Tump and Pipton long barrows). See Fig.1.1.

The next geometrical pattern to be discussed is what I refer to as "Petal Geometry." And in Chapter Five, I will show how this second pattern could have been used to set out the great henges of the Middle Neolithic period (circa 3200-2800 BC). My main case study for this chapter will be the Arbor Low Henge (Derbyshire). Again, I shall start this chapter with a discussion about the general archaeology associated with these great henges as well as assessing their building techniques and then follow with a detailed review of Arbor Low Henge - including its archaeology and experimental reconstruction. After that I will demonstrate how this same Petal Geometry can also work with the design of another henge i.e. Stones of Stenness (Orkney). See Fig.1.1. As before, I have chosen these henges because of their free, unlimited access should the reader wish to measure these earthworks for themselves.

Chapter 6 leads into the third geometrical variation, which I refer to as the "Station Stones rectangles" (so named after Stonehenge's famous four sarsen stones configuration). For sure, I cannot state that the original builders at Stonehenge used the very same technique for setting out this four stone arrangement as I do but if they did then it struck me as odd that we do not find similar rectangles elsewhere other than at Stonehenge. This oddity forced me to investigate the geometrical designs at other stone circles. What if the rectangles do exist amongst the other stone circles but the formation is not immediately apparent because of the presence of other additional standing stones placed upon the same circumference of their respective circle? It was this question that prompted me to look for these rectangles in Aberdeenshire. So, for this case study I shall discus Stonehenge's Stations Stones rectangle as well as a number of rectangles found amongst three Scottish Recumbent Stone Circles (RSCs). See Fig.1.1. Unfortunately, the reader would need special permission to measure Stonehenge's rectangle however, access to the Aberdeenshire RSC case studies is both free and unrestricted.

The final chapter, Chapter Seven, offers some additional reflections as to how I came about devising my Occam's Razor Solution. It explains the reasoning as to why I chose one course of ideas as opposed to other alternatives. Certainly, the essence of this book revolves around the difficult subject as to whether or not we can identify those processes involved between the *design and construction* of British Neolithic ceremonial and funerary monuments. That is, what were the procedures involved from the moment a Neolithic builder conceived (in their mind) the shape and form of a structure they intended to build. Now, because there is "little or no" archaeological evidence for accurate precision tools or other "surveying equipment" capable of skilful design then the task ahead for me is difficult.

At the end of this book I offer an Appendix which describes my experience of building a "Neolithic Henge." Built in 2008, and referred to as "Nesshenge", it is my replication of the Stonehenge earthwork. Surprisingly, it has now stood in the Ness Botanic Gardens for the last 15 years. And this Appendix allows me to report in full about its original construction and the effects of its ongoing duration at the Gardens.

Clarifications

I do need to clarify the use of some conventional terms that I will be using throughout this book. In the first instance, I shall be using the imperial format for presenting my measurements, followed and where applicable, by their metric equivalent. This is mainly the case with those measurements shown in the forthcoming tables and, thus, I am trying to avoid too much unnecessary repetition with the long barrow and henge reconstructions. In no way am I implying at all that the British prehistoric communities were using a modern-day imperial measuring system (or its equivalent metric system).

Secondly, regarding the accuracy of both measurement and orientation data presented in this book, I should point out the difficulties of measuring those extant monuments that have stood in the ground for nearly 6000 years. Whilst I have meticulously surveyed the extant long barrows, henges and stone circles discussed here (as well as their experimental reconstructions), measuring their detail is a task not without its difficulty. For instance, henge ditches both erode and silt up, their banks collapse and spread out; additionally, circle or tomb stones lean, move and fall. Moreover, the ground upon which a Neolithic monument stands swell or sink depending upon factors such as rainfall, frost and snow. As such, I introduce a degree of tolerance (or a margin of error) with my presented data; thus for measuring individual orthostats, I operate at plus or minus half an inch (measurements being taken at the base of the orthostat). For large earthworks such as Arbor Low henge then their "longer" measurements (e.g. diameters) are presented at plus or minus one foot (0.3048m). For any GPS data, this is presented at plus or minus 1-degree azimuth (orientation being based upon the direction of True North) and any GPS distance measurements are presented at plus or minus 10m.

Regarding the Astronomy

A by-product of my experimental research is that the geometry I use for reconstructing the ground plans of monuments provides a solution to those complex astronomical alignments that are often associated with extant Neolithic architecture. Thus a fundamental conclusion from my experimental data is that the Neolithic builders did not need to spend years and years of observing the movements of the sun and moon. And I will explain throughout this book how they achieved this. Furthermore, I will also be including those aspects of positional astronomy which have materialised during my experimental reconstructions. Notably, for this particular book and my explanations of astronomy, I shall rely upon the wisdom of archaeologist Aubrey Burl (who was once a leading expert on archeoastronomy). He provides a useful guidance for the astronomical orientation data mentioned in this book and Table 1.1 shows a general guide to those observations for the positions of solar rising and setting azimuths spread across the "Neolithic British Isles."

An important point to note here with Burl's astronomical data (listed in Table 1.1.) is the variation in azimuth readings for both a sunrise and sunset. As the angle of latitude increases from 50 degrees to 60 degrees there is a corresponding adjustment in the angle of azimuth.

Finally, in his paper "*Science or symbolism: problems of archaeo-astronomy*," Burl has also provided some particularly useful calculations for those astronomical alignments involving the Aberdeenshire Recumbent Stone Circles (Burl 1980). As such, I shall rely upon his wisdom when discussing their astronomy in Chapter Six.

Table 1.1. Times of Sunrise and Sunset in southern, central and northern Britain (after Burl 2000, 25).

Latitude	Region	Mid-summer Rise	Mid-summer Set	Equinox Rise	Equinox Set	Mid-winter Rise	Mid-Winter Set
50 degrees	Land’s End	51	309	90	270	129	231
55 degrees	SW Scotland	45	315	90	270	135	225
60 degrees	Shetlands	35	325	90	270	145	215

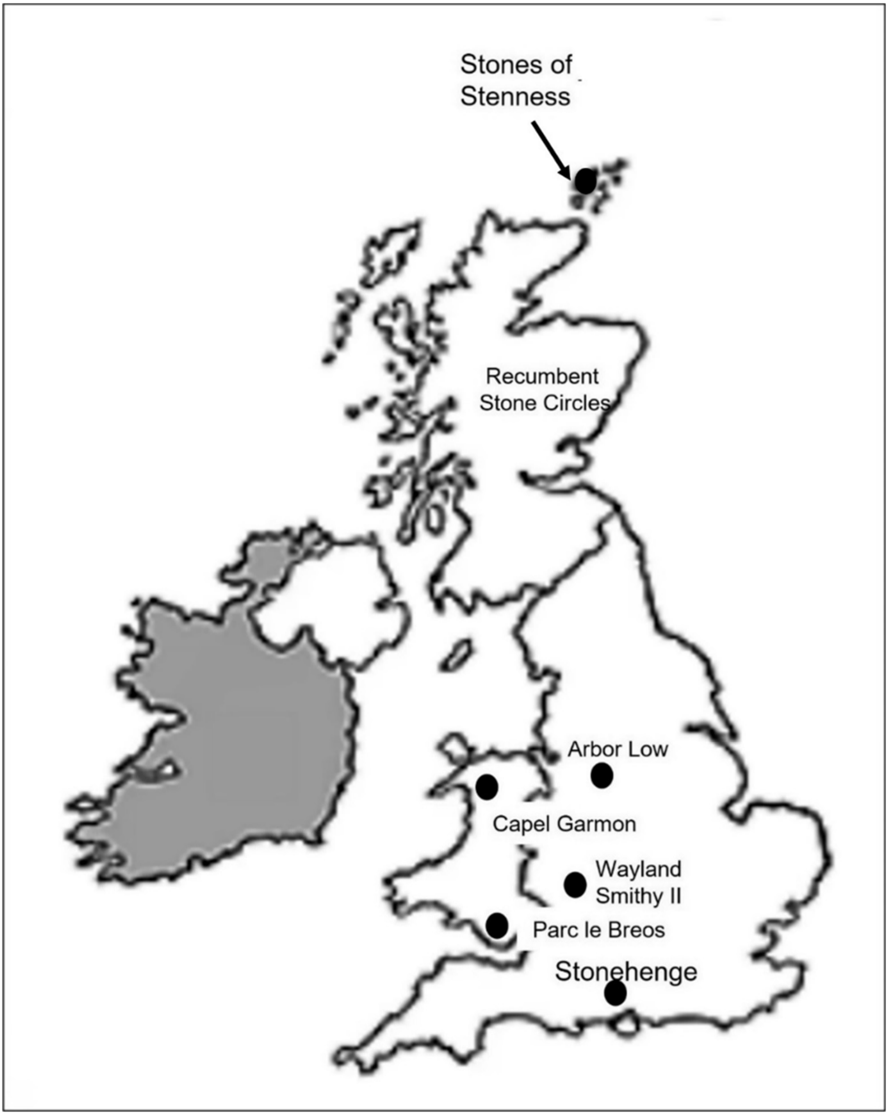

Fig. 1.1. The general location of the main sites mentioned in this book.

CHAPTER TWO

LITERARY REVIEW: MEASUREMENTS AND ASTRONOMY

Importantly, and to the best of my knowledge, no other researcher has proposed the same combination of experimental methods that I have. Nor has anyone attempted to practically test their theories in the manner that I do. Still, I need to discuss a review of the works of others who have intimated similar themes to my own. This is because my rope experiments have identified how "units of measurement" can materialise during design layout. They also create corresponding astronomical orientations that capture both solar and lunar phenomenon. But discussing the work of others is not an easy task as the volume of both traditional and evolving theories and opinions, concerning British prehistoric metrology and astronomy, have grown enormously these last few years. Thus, it is impossible to review every idea raised by others in this field of research. Therefore, I shall confine my literary review to those sources which, in my opinion, I think are pertinent to the contents of this book.

The Antiquarians

In the first section I discuss the work of the antiquarian William Stukeley who was, perhaps, the first researcher to propose the existence of a unit of measurement inherent within the construction of British prehistoric monuments. Then I shall consider the ideas of Flinders Petrie and Alexander Thom who have both intimated the use of, albeit different units. And the latter, of course, was to become a pioneer of archaeo-astronomy.

William Stukeley (1687–1765 AD)

Visiting the ruins of Stonehenge in the 18th Century AD must have been an unforgettable experience for the antiquarian and physician Dr William Stukeley. Notably, he had an eye for accuracy as many of his excellent drawings provide glimpses as to what state the monument looked like back then, almost two and a half centuries before the major restoration works of the early 20th Century AD. And, no doubt, it was this eye for detail that led him to propose that Stonehenge was so accurately built because the original builders used a particular unit of measurement to build it. He referred to this unit as a Druid's Cubit (Stukeley 1740,12). The name for the measurement being based upon an ancient Hebrew and Egyptian cubit, the length of which was naturally determined from the tip of the elbow to the tip from the fingers of the same arm i.e. or to be more precise 20.8 inches long. Certainly, it was no coincidence that Stukeley christened this measurement a Druid's Cubit because he had erroneously believed Stonehenge to have been built in 460 BC by the British Iron Age religious priests, the Druids (ibid,65). But, before continuing with my review, I need not criticise him too much about his incorrect timing for the building of Stonehenge, after all he did not have the luxury of our modern-day carbon dating! Still, we now know that the primary ditch and bank earthwork dates to 3000 BC whilst the main sarsen stone settings at Stonehenge were built around 2500 BC – that is, two and a half thousand years before the appearance of the British Druid.

Stukeley's cubit was deduced after he (with the aid of Lord Winchelsea) had made over 2000 separate measurements at Stonehenge (Hayman 1997,66). What is striking about the data is that Stukeley claimed that all of his measurements related (proportionally) to the cubit (see Burl & Mortimer 2005,112-4). Taken at face value, this would be quite a significant result in favour of his observations. However, when his poor ability to calculate the respective arithmetic is considered then one wonders about the authenticity of his conclusions. Unfortunately, it appears to me that mathematics was not his greatest strength. Let us look at a few examples which I (and no doubt others) have noticed amongst his work. For instance, his calculation as to how the dimensions of Stonehenge's Sarsen Stone Circle were determined are based upon the following assumption:

> "The intention of the founders of Stonehenge was this. The whole circle was to consist of 30 stones, each stone was to be 4 cubits broad, each interval 2 cubits. 30 times 4 cubits is twice 60: 30 times 2 is 60. So that thrice 60 completes a circle whose diameter is 60." (Stukeley 1740,16).

When the above mathematics are performed correctly then it can be seen how errors readily manifested into Stukeley's arithmetic: he had calculated the sarsen circle to possess a diameter of 60 cubits (i.e.104 ft) and that its circumference would then be equal to 180 cubits (i.e. 312 ft): that is *"thrice 60 completes a circle whose diameter is 60"*. The error is obvious, he had simply multiplied 60 x 3 and not included the factor of pi within the equation. Thus, when correctly calculated using pi the answer is 326.8 ft, a difference of 14.8 ft or 8.5 cubits - and this gives us an overall total of a cumbersome 188.54 cubits. Similarly, when his measurements for features such as the Trilithon stones are compared with relatively recent measurements from other reliable sources published elsewhere then errors once again can be seen. (See Table 2.1).

Table 2.1. Comparison between Stukeley's Trilithon measurements and Newall's.

Height of Trilithons (including lintel stone)	Stukeley's Measurements (Stukeley 1740)	Newall's Measurement (Newall 1959)	Difference in height
Stone No. 51-52; 59-60	13 cubits (22.5 ft)	20 ft	- 2.5 ft
Stone No. 53-54; 57-58	14 cubits (22.25 ft)	21.25 ft	- 1 foot
Stone No 55-56	15 cubits (26 ft)	22.5 ft	- 6 inches

The differences in Table 2.1 are only minor and it might have been tempting for Stukeley to "round-up" his survey data to his nearest cubit. In other words, he probably relied upon estimating his measurements to some degree. Furthermore, his errors continue when his "longer" measurements are also compared with corresponding equivalents quoted elsewhere. For example, he stated that the diameter of Stonehenge's Outer Ditch is *"4 times 60 cubits, which is about 410 ft"* (Stukeley 1740,33). Despite the mathematical calculation being incorrect (4 x 60 cubits is actually equal to 416 ft and not 410 ft), his dimensions of 410 ft for the diameter of the ditch far exceeded the 360 ft measurement achieved by modern survey, in fact by almost 50 ft (see Aveni 2008,87; Burl 2000,354). And, as a final example, Stukeley's quoted the length of the main North Cursus at Stonehenge was 6000 cubits long or 10,400 ft, alternatively, Newall quoted a more reliable measurement of 9090 ft (see Newall 1959,39).

Why Stukeley made such errors remains unknown. Possibly, as some have proposed elsewhere, he might have been intentionally falsifying his figures in an effort to give credence to his philosophical belief that Stonehenge was built by the "intelligent" Iron Age British Druids (e.g. Hayman 1997; Burl & Mortimer 2005). Certainly, it looks to me that Stukeley was attempting to align his measurements towards a possible sexagesimal system with a base of 60 using proportional units of 15, 30, 60 and even 6000 cubits. Could this counting system be the reason for Stukeley to “cook the books” in some manner to support his beliefs in favour of a “superior intellectual Druid.” Yet, even with his tendency to “round up the numbers” I cannot ignore the point that he did perform over two thousand measurements at Stonehenge alone and, surely, not all of his data can be wrong, he must have been on to something? Additionally, the use of the human elbow as a “measuring tool” does make valid sense to me (see next chapter). Thus, in the context of metrology alone, then Stukeley’s cubit is worthy of further investigation.

Flinders Petrie (1853–1942 AD)

Flinders Petrie performed a survey at Stonehenge and he identified two further specific units of measurement relating to its design (neither of which were proportionally related to Stukeley’s cubit). Incidentally, like Stukeley, Petrie also miscalculated the date for the original building of Stonehenge. This time his builders of Stonehenge lived amongst the British “Dark Ages” (circa 450-850 AD) and they somehow managed to have “reused” a unit of measurement which was first introduced in Britain during the earlier Roman occupation, circa 41- 410 AD (Petrie 1989,27-30). Thus, according to Petrie’s rationale, the building of Stonehenge must have taken place after the Romans had left, sometime between 462-720 AD. Besides using erroneous astronomy to date the construction of the monument he also supplemented his logic by quoting from the chronicles of both Nennius, circa 850 AD, and Geoffrey of Monmouth, circa 1140 AD. These authors write of a legendary meeting that took place around 462 AD, when the indigenous Britons and the incoming Saxons met to discuss a truce between their battles at Amesbury with the latter slaughtering the former at this meeting, leaving behind Stonehenge as a memorial to the massacre (ibid,28). Overall, Petrie believed the main phase of construction occurred between 500-600 AD. But again it will be prudent for me not to criticise Petrie for his anachronisms about when Stonehenge was built as it is more important for me to discuss his survey data; especially as he was a professional surveyor (Lancaster Brown 1977,260) and it would seem to me that Petrie was less likely to have made the same mathematical mistakes as Stukeley did.

After surveying Stonehenge in 1877, Petrie analysed his data and subsequently deduced that Stonehenge had been designed using two different units of measurement. Accordingly, the first unit was based upon a Phoenician measurement being 22.5 inches long (0.5715m). His second unit was the Roman measurement (mentioned above) and it measured 11.6 inches (0.2875m). Interestingly, Petrie concluded that Stonehenge had been built in two phases; with the Phoenician measurement being used as a unit for the setting out the earlier earthwork's ditch and bank; whilst the later Roman Foot had been used to set out the later central sarsen stone settings (Petrie 198,23). Indeed, such an observation does indeed concur with our current knowledge about the sequences of construction at Stonehenge with the Outer Ditch and Inner Bank earthworks being built about 500 years before the central sarsen stone settings i.e. the ditch and bank dating to around 3000 BC; the central sarsens features dating to around 2500 BC (Parker Pearson 2012).

To help him survey Stonehenge, Petrie used a surveyor's chain capable of accurately measuring detail to the nearest tenth of an inch (Petrie 1989,3). But despite such accuracy that this equipment brought, I have still been able to find a number of discrepancies amongst his published survey data. Let us look at one discrepancy in particular which is associated with his 22.5 inch Phoenician unit of measurement. Although Petrie does not explain how this "early" unit arrived in Neolithic Britain, I was quite excited to see that he had found a unit sharing similar dimensions to those I have also observed at numerous other Neolithic monuments such as the Recumbent Stone Circles of Aberdeenshire (Hill 2021a, 40-70) as well as measurements at Stonehenge (Hill 2009d; Hill 2009e). However, when I scrutinised how he deduced this Phoenician unit, I found a serious flaw in his logic. Let me explain further.

His 22.5 inches unit was deduced by analysis of the dimensions taken from two of Stonehenge's primary features: the Outer Ditch and the Inner Bank (Note - no other primary features (such as the entrances) were measured to substantiate this unit of measurement). For some unknown reason (at least to me) he stated that the ditch and bank contained similar proportions:

> "Taking the earth circle first, as giving more measurements for inter-comparison, the bank appears to have been equal in width to the ditch.....This is 225 inches, plus or minus 4 inches" (Petrie 1989,22).

He then goes on to list these two measurements which define the diameters of the bank and ditch, as well as a third measurement which marked out the neutral point between them as follows:

a) The diameter of the bank being 3595 inches (299.6 ft)

b) the diameter of the neutral point between the ditch and bank being 4045 inches (337.1 ft)

c) the diameter of the Outer Ditch being 4495 inches (374.6ft)

From these three measurements Petrie deduced that they can be expressed in multiples of a "longer unit of measurement" of 225 inches i.e. (a) 225 x 16 = 3595; (b) 225 x 18 = 4045; (c) 225 x 20 = 4495. Now, this longer unit of 225 inches can also be reduced to a "shorter" unit by simply dividing that figure by 10, hence he concluded that the Phoenician unit of measurement of 22.5 inches was this length (Petrie 1979,22). Unlike Stukeley, the mathematics are fine here, it is just that Petrie's measurements contradict what we know today about the dimensions of the Outer Ditch and Inner Bank. The important point to consider is that they are not equal in width as Petrie suggested. Yes, the width of the bank matches Petrie's 225 inches (18.75 ft) BUT the width of the ditch is 13.5 ft (Hill 2009d) - almost 5.25 ft shorter! Now we have discrepancy relating to his detail. Moreover, Petrie specified a measurement of 374.58 ft for the perimeter of the ditch, which is about 14 ½ ft in excess of the 360 ft measurements quoted by both Aveni (Aveni 2008,87) and Burl (Burl 2000,354).

It really does surprise me that Petri could make such a mistake about the width of the ditch being equal with the width of the bank given his experience as a professional surveyor. One explanation I thought about was that the ditch was not as clearly visible on the ground as it is today. Maybe, it looked wider when Petrie measured it. However, during the 1920's, retired Lieutenant-Colonel William Hawley (1851–1941), acting as Stonehenge's "resident" archaeologist, provided a reliable view as to what the ditch looked like, and his survey measurements were taken just 40 years after Petrie's visit to the site. In fact, Hawley excavated greater parts of the ditch and has recorded that its widest width was no more than 14 ft (Cleal *et al.* 1995). Unfortunately, if I take Hawley's observations into account, then Petrie's authenticity for the existence of Phoenician unit of measurement seems weak to me due to his miscalculations about the width of the ditch.

But what of Petrie's Roman Foot at Stonehenge? He recorded that the diameter of the Sarsen Stone Circle as being 97.325 ft (Petrie 1989,23). But Burl states a diameter of 97 ½ ft, a measurement first observed by John Aubrey's survey of 1666 and much later confirmed by Alexander Thom in 1973 (Burl 2006,30). Whilst the discrepancies for these measurements may be marginal, I suspect that Petrie might have been falsifying his data in a way that Stukeley did. Petrie's diameter of 97.325 ft just happened to be (conveniently) ten units of 11.6 ft (i.e. one Roman Foot). Now, it looks to me that he found a fortuitous, convenient measuring system that could chronologically explain the two phases of construction he proposed at Stonehenge. However, Petrie did provide a footnote to his Roman Foot deductions, expressing his concern that he had not completed a full

"Inductive Metrology" analysis for his Roman Foot measured at Stonehenge (Petrie 1989,23). Thus, the case for his Roman Foot remains unanswered. But let us not forget that pacing and measuring with the human foot is a significant "surveying tool" and a viable option for future consideration.

Alexander Thom (1894-1985 AD)

In his book, *Megalithic Sites in Britain,* Alexander Thom, a former Professor of Engineering at Oxford University, presented survey data supporting the type of metrology, geometry and astronomy which he believed the prehistoric communities used to set out the design of their stone circles. Certainly, the sheer volume of data presented by Thom far surpassed the findings by the likes of Stukeley and Petrie. Indeed, Thom had investigated the geometrical designs of at least 300 stone circles (Thom 1967,1-3). Undoubtedly, his observations were meticulously gathered in such a way that the accuracy of his findings were acknowledged by many of his critics (Barnett & Moir 1984). Moreover, he continued to publish further books and over a dozen journal articles providing additional realms of survey data in support of his conclusions. Unfortunately, such is the extent of his research that it is far beyond the scope of this chapter (or even this book) to provide a full assessment of Thom's work. Therefore, I will provide a summary of those findings which can be broken down into three main categories: Geometry; Metrology (the Megalithic Yard); Astronomy.

Thom's Geometry

The majority of Thom's geometrical theories focused mainly on showing how the design of stone circles was achieved by using "Pythagoras triangles." Furthermore, he believed that the stone circles builders used Pythagorean theorem to set out a range of shapes for their circles, (e.g. such as ellipses and flattened circles). Certainly, he thought that the British Neolithic circle builders possessed mathematical knowledge more appropriate to those mathematicians who would appear two thousand years later in history, in fact amongst the people of Iron Age Greece (circa 600-50 BC). Indeed, talking about his "expert builders," he insisted that:

> "The basic figure of their geometry, as is ours, is the triangle. Today everyone knows the Pythagorean theorem which states that the square of the hypotenuse of a right-angled triangle is equal to the sum of the squares on the two other sides. We do not know if Megalithic man knew the theorem….but he was feeling his way towards it." (Thom 1967,26).

For sure, Thom's mathematical analysis of the dimensions of stone circles led him to further insist that there were certain specialists living amongst the British Neolithic communities who had actually pre-empted the principles of Pythagoras by several millennia:

> "It is remarkable that 1000 years before the earliest mathematicians of Classical Greece, people in these Islands…had a practical knowledge of geometry and were capable of setting out ellipses based upon Pythagorean triangles." (ibid,3).

Of course, Thom's anachronistic view of Neolithic society raised eyebrows amongst many of his contemporary prehistorians. And, needless to say, his vision of exceptional mathematicians living amongst the preliterate Neolithic communities posed a direct challenge to many of the orthodox views about British prehistoric culture as generally accepted by most archaeologists at that time (Ruggles 1999,8). Indeed, Professor Richard Atkinson best summarised the problems raised by Thom:

> "No one I am sure is going to question the accuracy ….of the evidence which Professor Thom has put before us. Where people are going to have difficulty is with the implications made." (Comments by Atkinson cited in Thom A.S. 1995,222).

Undoubtedly, Thom's anachronistic view of the intellectual capabilities of prehistoric society has been adequately addressed elsewhere and I do not need to cover (nor particularly agree with) what has been said by many others (Lancaster Brown 1977; Hayman 1997; Chippendale 1999; Ruggles 1999; Burl 2006; Johnson 2008). Perhaps though, we should completely ignore Thom's anachronisms and approach his work in other ways. More so, as I demonstrate later in this book (with my Petal Geometry), there are other ways to set out triangles without resorting to Pythagoras theorem. And, significantly, let us not forget that the practical application of triangular shapes was no doubt important and essential for the Neolithic builders. For instance, the correct angle of pitch for building earthen ramps was vital in order for the Stonehenge builders to raise their heavy sarsen lintel stones 13 ½ ft (4.1m) above ground level in order to sit them upon their corresponding uprights (Hill 2009d); similarly, stone holes which had to possess, at the correct angles, sloping gradients at one side of the hole so as to allow heavy standing stones to be lowered, manoeuvred and raised into position. Yes, familiarity with triangular shapes and respective angles were important to the Neolithic communities and, if we ignore the anachronisms, then Thom was right to raise this observation for our attention. Today, we