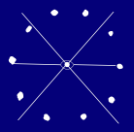
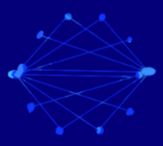


A Matter of Perspective

Each individual has a natural tendency to view the world as if he stood at the centre of it. This human trait in nearly everybody has been the main reason why we still don't understand what purpose the stone circles constructed by our ancient ancestors some 5000 years ago served. Without exception antiquarians, archaeologists, engineers and archaeo-astronomers have all steadfastly stood at the centre of these ancient monuments and have measured and searched for alignments between the megaliths radiating out from them and the Sun on the horizon from their viewing position at the origin; the centre of the circle. It is almost as if there is no other possibility and that if no alignments of any significance can be found from the centre, then none were meant, hence the impasse and the reason why no progress has been made in over 200 years of study. However, if a more open-minded person was to consider that there are other possible viewing positions and stand on the edge of the stone circle just beside the easternmost megalith and look west across the circle to the megaliths positioned along the western arc of the circle, and beyond to the setting Sun on the horizon they would find that three megaliths aligned perfectly with the Sun on the days corresponding to the Winter Solstice, the Spring and Autumn equinoxes and the Summer Solstice. The same would be true for a second viewing position on the opposite western-most edge of the circle where this time looking eastwards across the circle to the Sun on the horizon at sunrise, again three megaliths perfectly align with the Sun on the horizon on the solar festival days corresponding to the equinoxes and solstices. Two peripheral viewing positions, one for sunrise alignments and the other for sunset alignments. This is a promising start as from the centre of the circle no convincing alignments were possible between the Sun and the megaliths on all four days of the equinoxes and solstices. There are however additional megaliths located around the stone circle. The second breakthrough is that it appears that they align with the setting Sun and rising Sun on the horizon from the two peripheral viewing positions on days that coincide with days when special bright stars are aligned precisely due South at either the start or the end of Civil Twilight when the Sun lies about 6 degrees below the horizon and it is just dark enough to view the brightest stars in the sky. The days when the alignments occur may have formed a calendar and that calendar may have been based on festival days dedicated to deities associated with bright stars that were aligned due South in the sky at Civil Twilight on those days.



Scottish Stone Circles. Top Callenish Isle of Lewis, Outer Hebrides, Centre Recumbent stone, Tomnaverie Stone Circe, Tarland, Aberdeenshire, Bottom Loanhead of Daviot, Aberdeenshire.

Stone Circle Calendrical Devices

We propose that the Scottish stone circles were prehistoric calendrical devices where festival days were indicated by days when the Sun on the horizon aligned with the stone circle's megaliths. The days identified by the alignments are shown to represent both solar festivals corresponding to the days of the solstices and equinoxes and stellar festivals corresponding to the alignment of bright stars due South in the sky at dawn or dusk more specifically at the start and end of Civil Twilight. The first idea that led to the discovery are that the alignments between the Sun and the megaliths are made, not from the centre of the circle but, from two viewing positions on the perimeter of the circle; one viewing position on the eastern edge of the circle facing westward to make alignments between the setting Sun anthe megaliths situated across the circle and the other viewing position located across the circle on the western perimeter facing eastward to make alignments with the rising Sun and megaliths on the eastern arc of the circle. The second critical element of the proposal that the stone circle was a calendar, is the finding that the days indicated by the solar alignments with the stones, marked days when bright stars were aligned precisely due South at Civil Twilight, when the Sun is six degrees below the horizon. The stars which were aligned due South at Civil Twilight on the days indicated by the solar alignments with the megaliths are amongst the brightest stars in the night sky, stars such as Betelgeuse, Spica, Deneb, Scheat, Antares, Arcturus, Capella, Alphard, Altair, Vega and Pollux. Only the brightest stars are visible at Civil Twilight and the alignment of these stars are proposed as marking festival days dedicated to stellar deities associated with these same bright stars that formed a pantheon of prehistoric gods. The solar and stellar festival days indicated by the alignment of the Sun and the megaliths divided the year into periods that would have provided a useful calendar as the nomadic hunter-gatherers became Neolithic farmers and allowed the people to venerate deities that may have been considered as bringing them good fortune with hunting, fishing, fertility and protection.

Easter Auquorthies Recumbent Stone Circle, Aberdeenshire believed to date to 3000BC

Introduction

The purpose of the Neolithic stone circles, constructed over five thousand years ago, has remained a mystery ever since back somewhere in the mists of time when the last people who knew, finally forgot or decided not to pass on the knowledge as to what their ancient ancestors had used them for. The research efforts of antiquarians and archaeologists over the past centuries have frustratingly revealed very little about these ancient monuments and how they may have been used. Some stone circles have megaliths that align with the Sun on the horizon at sunset on the days of the winter and summer solstices but the majority of stone circles do not exhibit such alignments on the days of either the equinoxes or solstices when viewed from the centres of the stone circles. Although the equinoxes can occasionally be indicated through the alignment of the Sun with megaliths positioned along the East-West axis, in the absence of solstice alignments in these same stone circles, there is no reason to consider that these occasional alignments are anything other than coincidental. This paper revisits the stone circles of Scotland in an attempt to determine why they were constructed, and how they may have been used by our ancient ancestors.

The clock-like or sundial-like appearance of the stone circles has led some, such as Gerald Hawkins to consider that they may have had some astronomical purpose. If, however, alignment between the megaliths and the Sun and stars was intended to indicate certain festival days, there is very little obvious evidence on the ground to support this idea. If the stone circles had a calendrical purpose, then it might be expected that the winter solstice, the spring equinox, the summer solstice and the autumn equinox would be obvious candidates for solar festival days, just as they are today. These solar festival days could have been indicated by the alignment of the megaliths with the rising and setting Sun on the horizon on those days from a viewing position within the circle. The first requirement is to determine the bearings of the Sun at sunrise and sunset on the days of the equinoxes and solstices at the time the stone circles were used. The date of construction of the stone circles and the period over which they were used is not known with any certainty but it is generally believed, from carbon-dating of organic matter associated with the circles, that they were first erected around 3000BC. The position of the Sun on the horizon at sunrise and sunset on the days of the solstices and equinoxes was determined using the archaeo-astronomy program SkyMap Pro II. The period selected for examination was from 3200BC to 2400BC allowing a period of two centuries prior to the estimated construction date and 600 years after this date to allow for a possible extended period of use of the stone circles.

Solar Festival	Azimuth of Sun on the Horizon									
	3200bc		3000bc		2800bc		2600bc		2400bc	
	Sunrise	Sunset	Sunrise	Sunset	Sunrise	Sunset	Sunrise	Sunset	Sunrise	Sunset
Winter Solstice	136˚45'26"	223˚14'55"	136˚42'54"	223˚17'23"	136˚40'36"	223˚19'33"	136˚36'56"	223˚23'18"	136˚33'57"	223˚26'19"
Spring Equinox	88˚58'44"	271˚23'11"	89˚18'40"	271˚2'55"	88˚56'4"	271˚25'47"	89˚15'42"	271˚6'2"	88˚52'6"	271˚29'47"
Summer Solstice	39˚19'52"	320˚40'6"	39˚22'33"	320˚38'0"	39˚25'6"	320˚34'57"	39˚29'10"	320˚31'27"	39˚31'44"	320˚28'29"
Autumn Equinox	88˚37'43"	270˚58'52"	89˚37'30"	269˚59'21"	88˚19'25"	271˚17'13"	88˚34'5"	271˚2'31"	88˚3'17"	271˚33'23"

Table 1 shows the relatively constant alignment of the Sun on the horizon on the days of the equinoxes and solstices over the period 3200bc to 2400bc

The position of the Sun on the horizon on the days of the solstices and equinoxes remained remarkably constant to approximately half a degree over the 800 year period examined indicating that if megaliths were aligned to mark these solar festival days then it would not matter significantly when the stone circles were erected or for how long they were used within the period examined. Even today some five millennia after the stone circles were built the alignments have moved by only around two degrees which is of the same order of magnitude as the angular width of a megalith viewed from the centre of the circle.

The precise angles chosen to examine the closeness of match between the stone circle megalith positions and the bearings of the Sun on the horizon at sunrise and sunset on the days of the equinoxes and solstices were those for the year 3000BC.

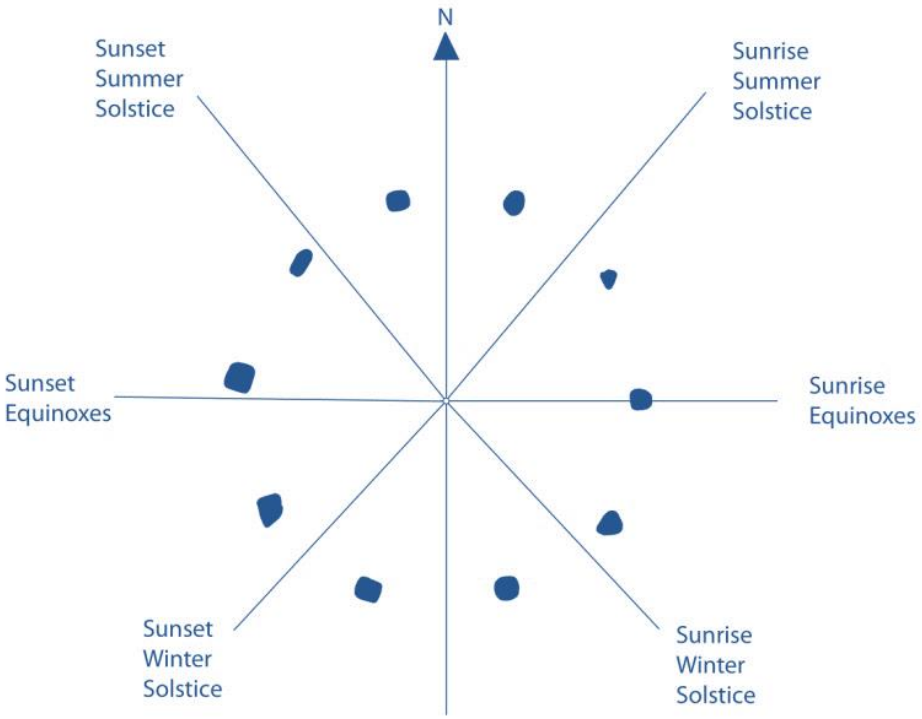


Diagram 1 shows the bearings of the Sun on the horizon at sunrise and sunset on the days of the solstices and equinoxes from the centre of the Loch Mannoch stone circle for 3000BC.

Diagram 1 illustrates that the days of the solstices and equinoxes, indicated by the position of the Sun on the horizon at sunrise and sunset are not indicated by the alignment of the Sun with the megaliths when viewed from the centre of the circle. The conclusion of this finding is that either the stone circles were not used to indicate the solar festival days or that we are looking for alignments from the wrong position. Some consider that for most circles, megaliths were simply placed evenly apart around the circumference indicating a symbolic positioning rather than a functional one. Examination of the bearings of stones from the centre reveal that whilst there is a general appearance of an even separation of stones, there are significant differences between the angles of arc between adjacent megaliths which may have been intentional and which need to be explored. Whilst the centre of the circle seems like the only logical place to stand and view alignments between the megaliths surrounding the viewer and the rising and setting Sun on the horizon, it should be considered that perhaps this deeply entrenched assumption may be wrong and the main reason why the purpose of the stone circles remains unknown after centuries of academic research. On reflection, there is perhaps a better position to make accurate alignments from or rather two positions that maximise the distance between the viewer and the stone to give the greatest accuracy of the alignment between the viewer and the stone and the Sun on the horizon. There are two positions on the perimeter of the circle, one on the western edge facing East across the circle to the rising Sun and the other on the opposite side of the circle on the eastern

perimeter facing West to the setting Sun that could have provided viewing positions; one for sunrises and the other for sunsets. These viewing positions minimise both the size of circle required because the circle's diameter or chords are used for alignment rather than its radius, and potentially the number of megaliths required to be erected is also minimised by allowing some stones to be used for alignment both at sunrise and sunset from the two separate viewing positions. By considering sunrise alignments and sunset alignments separately, two viewing points can be found where megaliths align with the rising Sun and the setting Sun on the solar festival days when they are positioned on the western edge and eastern edge respectively of the stone circle's perimeter facing each other across the circle. Despite the feeling that two viewing positions are unnecessarily complicating the process of alignment, the fact that two different positions are required rather than the single central viewpoint has no real disadvantage in that any alignment of the Sun at sunrise or sunset would be carried out at two separate times of day anyway.

Two Viewing Positions

Currently there is no hard, archaeological evidence on the ground to suggest the precise positions of the two proposed viewpoints, if they ever existed. Perhaps wooden posts were originally erected to mark the viewing positions, which have long since decayed, or if small paving stones were placed on the ground to mark these positions, they too are now buried or lost, or perhaps more likely, the position was simply indicated by the visual alignment of three megaliths that only aligned at the required viewpoint so no physical marker was required. The method of establishing the possible positions of the proposed viewpoints is to use the alignments between the megaliths and the Sun on the horizon on the days of the summer solstice, the autumn and spring equinoxes and the winter solstice. The first stage is to identify the megaliths that are used to make the alignment between the Sun on the horizon for the equinoxes which occur on the days when the Sun has a bearing of around 89.5 degrees at sunrise and 270.5 degrees at sunset. The megaliths used for alignment at the equinox are proposed as the megaliths closest to the East-West line that passes through the centre of the circle. One megalith on the eastern perimeter is identified as the megalith that aligns with the Sun at sunset on the days of the equinoxes when viewed from a viewpoint on the western perimeter and a second megalith on the western perimeter is identified as the megalith that aligns with the Sun on the horizon at sunrise on the days of the equinoxes when viewed from a viewpoint on the western perimeter.

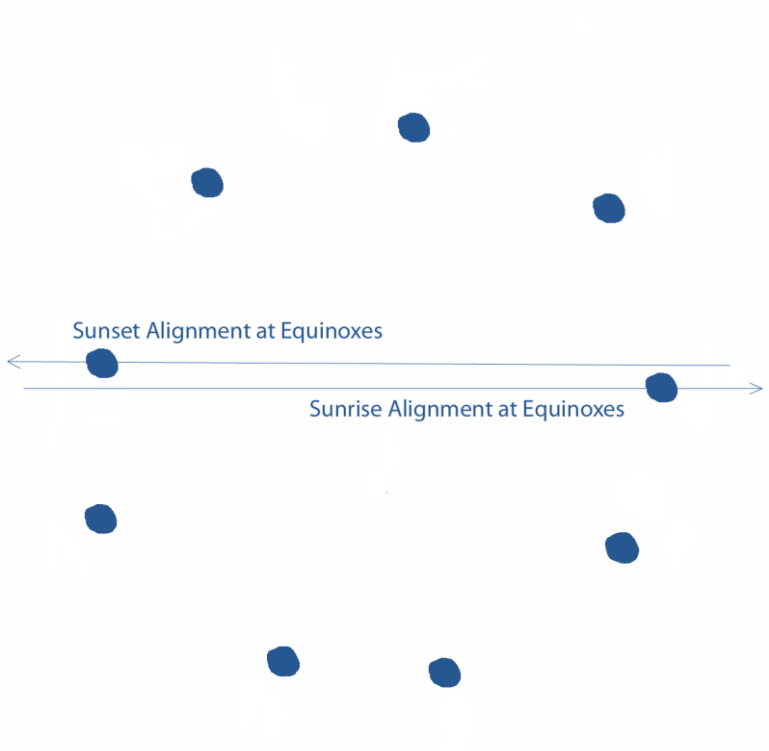


Diagram 2 Stage 1 of determining possible peripheral viewpoints. Identification of Equinox Megaliths and lines on which the viewpoints are located

Having drawn a bearing line of approximately 89.5 degrees through the eastern sunrise equinoxial megalith and a bearing line of approximately 270.5 degrees through the western sunset equinoxial megalith it can be seen that in many stone circles the stones describing East and West are slightly displaced so that the viewing positions are on a line that runs beside the eastern and western megaliths looking directly across the circle to align with the megaliths directly opposite the viewing point. At this stage the viewing position can only be determined as a line and requires a second alignment to pinpoint the position of the viewing point on that line. The second alignment that allows the identification of the viewing points is to consider the alignment of megaliths with the Sun on the horizon at the summer solstice. A bearing line was drawn through megaliths aligned with the rising and setting Sun at the summer solstice. The megaliths chosen for alignment at sunrise and sunset at the summer solstice were the second most northerly stones erected in either hemisphere of the stone circle. The bearing of the lines drawn through the approximate middle of these megaliths were 39.4 degrees and 320.6 degrees representing the alignment of the Sun on the horizon at sunrise and sunset respectively on the day of the summer solstice. When the bearing lines for the summer solstice and the equinoxes are extrapolated, they intersect with the equinoxial lines at two points; one East of the stone circle and the other West of the stone circle, these represent the viewing positions (x and y).

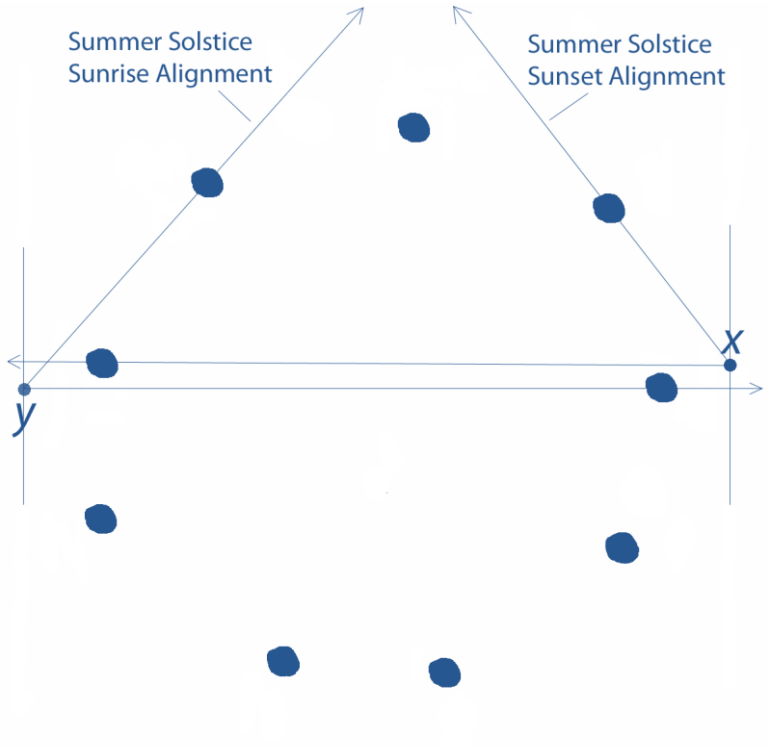


Diagram 3 The intersection of the equinox and summer solstice alignments identify the two possible viewing points " x" for sunset alignments and " y" for sunrise alignments with the Sun on the horizon.

Having established two viewing points that allow the days of the equinoxes and summer solstice to be identified by alignment of the Sun on the horizon with four megaliths, two for sunrise alignments and two for sunset alignments, the idea can be tested to see whether the alignment of two further megaliths from these viewing points aligns with the Sun at sunrise and sunset on the day of the winter solstice. The bearing of the Sun at the winter solstice is 136.7 degrees at sunrise and 223.2 degrees at sunset. If the proposed peripheral viewpoints are correct then it is to be expected that an alignment with the Sun on the horizon on the day of the winter solstice will align with a megalith from these viewing positions. Drawing the lines corresponding to the winter solstice alignment with the Sun at sunrise and sunset from the points x and y allows us to test whether they coincide with two megaliths situated on the south east and south-west perimeter of the stone circles.

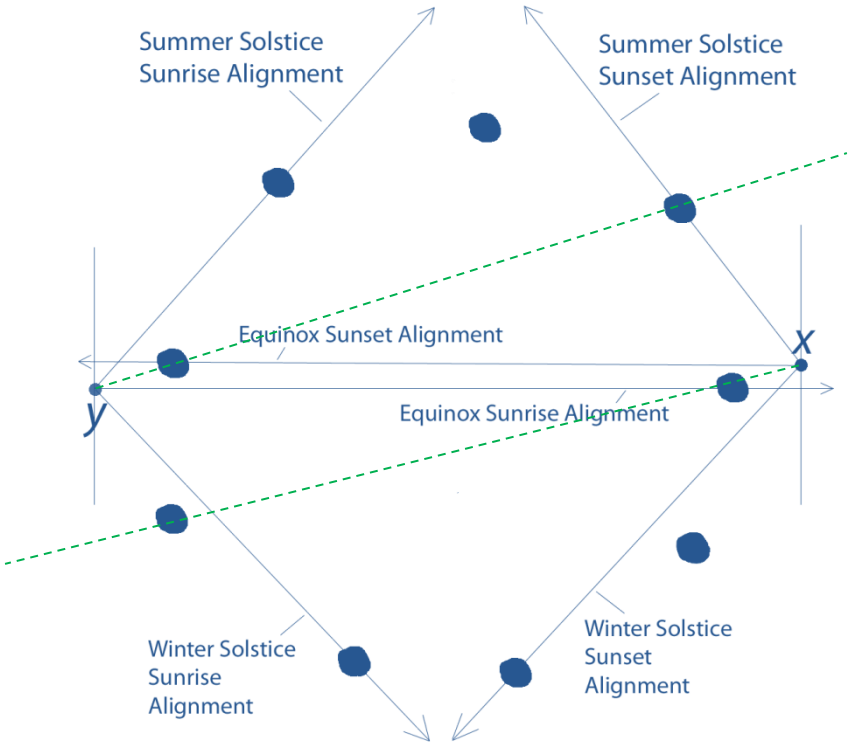


Diagram 4 Shows that the Winter Solstice sunrise and sunset alignments from viewpoints x and y coincide with megaliths positioned in the South-East and South-West quadrants to support the idea that if two peripheral viewpoints were used, they could have marked the days of the equinoxes and solstices. The stone alignment dashed lines in green show how the viewing positions could have been easily found without the need for any physical marker of that position on the ground, or the bearings of the Sun on the horizon at the solstices, by simply aligning the two stones bisected by the green dashed lines and the stone lying directly opposite the viewing position on the East-West Axis.

Eight stone circles (Loch Mannoch, Aquorthies Manar, Sunhoney, Cullerlie, Leys of Marlee, Blindwells and Colen) judged to be in a reasonable state of preservation were selected to determine whether they all could have been used to identify the days of the spring and autumn equinoxes and the days of the summer and winter solstices. The positions of the peripheral viewpoints (x and y) was firstly established as illustrated in Diagrams 2 and 3 by considering the locations where the bearings of the Sun on the horizon at sunrise and sunset on the days of the equinoxes and summer solstice coincided with the alignment of four megaliths and identifying the points of interception as the viewpoints x and y. Having established the viewpoints, the stone circles were re-examined to determine the closeness of the alignment occurring between the Sun on the horizon with a fifth and sixth megalith on the day of the winter solstice from those viewpoints. The method and results of the analysis are described in Appendix I.

It was discovered that for each one of the eight stone circles a viewing point, x for sunset alignments and y for sunrise alignments, could be established which gave perfect or very close alignments (within the width of the megalith) with the Sun and the megaliths on all

four solar festival days represented by the days of the equinoxes and solstices for each of the eight stone circles.

Although the stone circles could have been used to identify solar festival days when viewed from the two proposed peripheral positions, only six of the nine or ten megaliths are required to mark these solar festivals and there are other megaliths in the circle, that could give a total number of fifteen alignments with the Sun on the horizon from the two viewing positions. If the hypothesis is correct then the additional nine alignments might be expected to also have marked days that had some significance to the people who erected the stone circles.

The viewing points, (x and y), for each of the remaining stone circles, as shown in Appendix II, were identified using the same set of criteria as used in the eight stone circle examples, that is, by utilising alignments between megaliths and the Sun on the horizon on the days of the solstices and equinoxes. Some circles have only two of the three possible solar festival alignments due to missing or displaced megaliths and in these cases in order to determine the possible viewpoints either the summer solstice and the equinox alignments or the summer solstice and the winter solstice alignments or the equinoxes and winter solstice alignments were used to determine the likely positions of the viewpoints on either side of the stone circle.

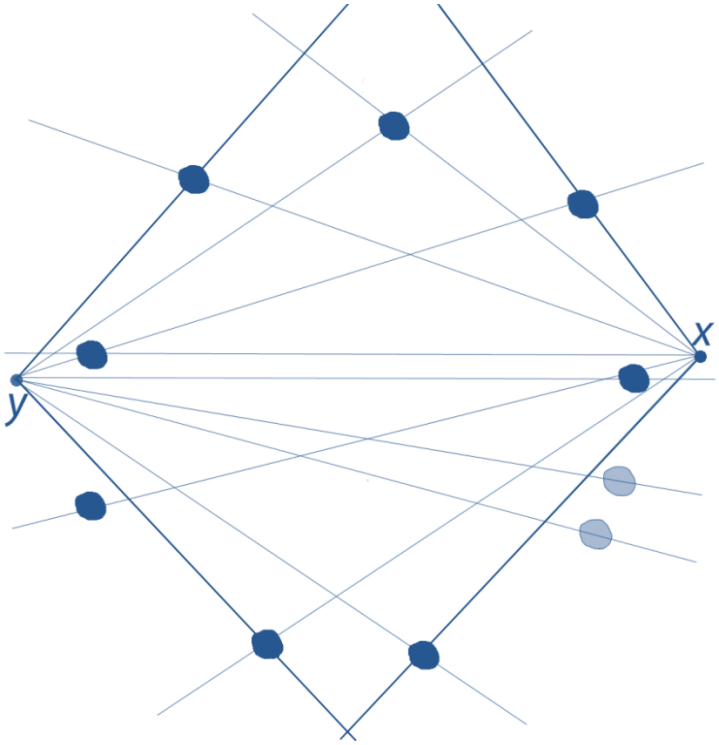


Diagram 5 shows the possible megalith alignments between the Sun at sunrise and sunset from the two viewpoints between the extreme possible positions of the winter solstice and the summer solstice (shown in bold lines). After determining the viewpoints x and y for each of the stone circles, the alignments from the viewing points with every megalith in the circle are drawn to bisect the remaining stones and these bearings are each measured relative to North.

Thirty-six Scottish stone circles surveyed and drawn by Thom, described and illustrated as plans in Megalithic Rings, A. & A.S. Thom, collated with archaeological notes by A. Burl in British Archaeological Reports, British Series 81, 1980 were selected for analysis together with the field notebooks of Professor Thom held at RCAHMS in Edinburgh. Each of the chosen stone circles was considered to be in a reasonable state of preservation with at least five stones remaining on a circular perimeter. The proposed viewing positions x and y were determined for each stone circle in the manner illustrated in Diagram 4 by overlaying the radial lines corresponding to the sunrise and sunset bearings of the days of the equinoxes and solstices over the stone circle plans and moving the vertex position vertically and horizontally relative to true North over the plans until the radiating lines aligned as closely as possible with the megalith positions on the days of the equinoxes and solstices. Having determined and marked the points x and y for each stone circle, the bearing of each megalith was measured relative to North from these viewpoints. The bearings were measured by drawing a line from the proposed viewpoint through the midpoint of each megalith and measuring the angle of that line relative to North thereby establishing the bearing where the Sun on the horizon at sunrise or sunset aligned with the megalith from that viewpoint. The North-South reference axis was drawn through the viewing point parallel to the North-South Axis established by Thom on the plan of the stone circle and the angles measured using a protractor to an approximate accuracy of plus or minus half a degree. The megaliths of the example stone circle are labelled a) to i) in Diagram 6. Stones a) and g) representing the sunrise alignments from y on the days of the summer and winter solstices respectively and stones c) and f) the sunset alignment from x on the same days. Stones a), b), c), f) and g) potentially could have been used for both sunrise and sunset alignments thereby minimising the number of megaliths required to provide this number of alignments in a stone circle of this design.

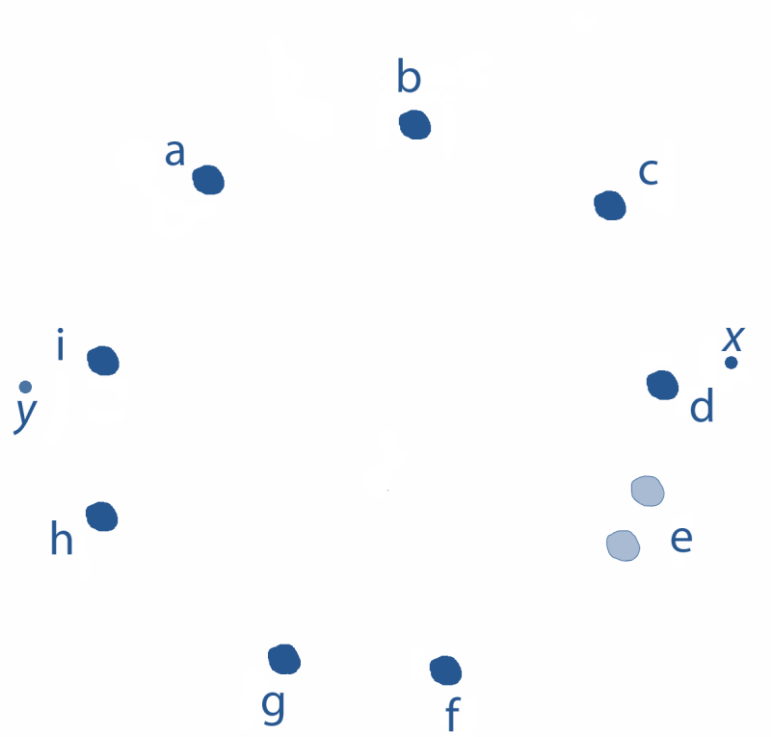


Diagram 6 shows the labels of a stone circle where each megalith aligns with the Sun on the horizon on the days coinciding with the peaks shown in Graphs 1 and 2. The two lighter shaded stones labelled "e" are proposed to be alternative megalith positions found on many of the stone circles.

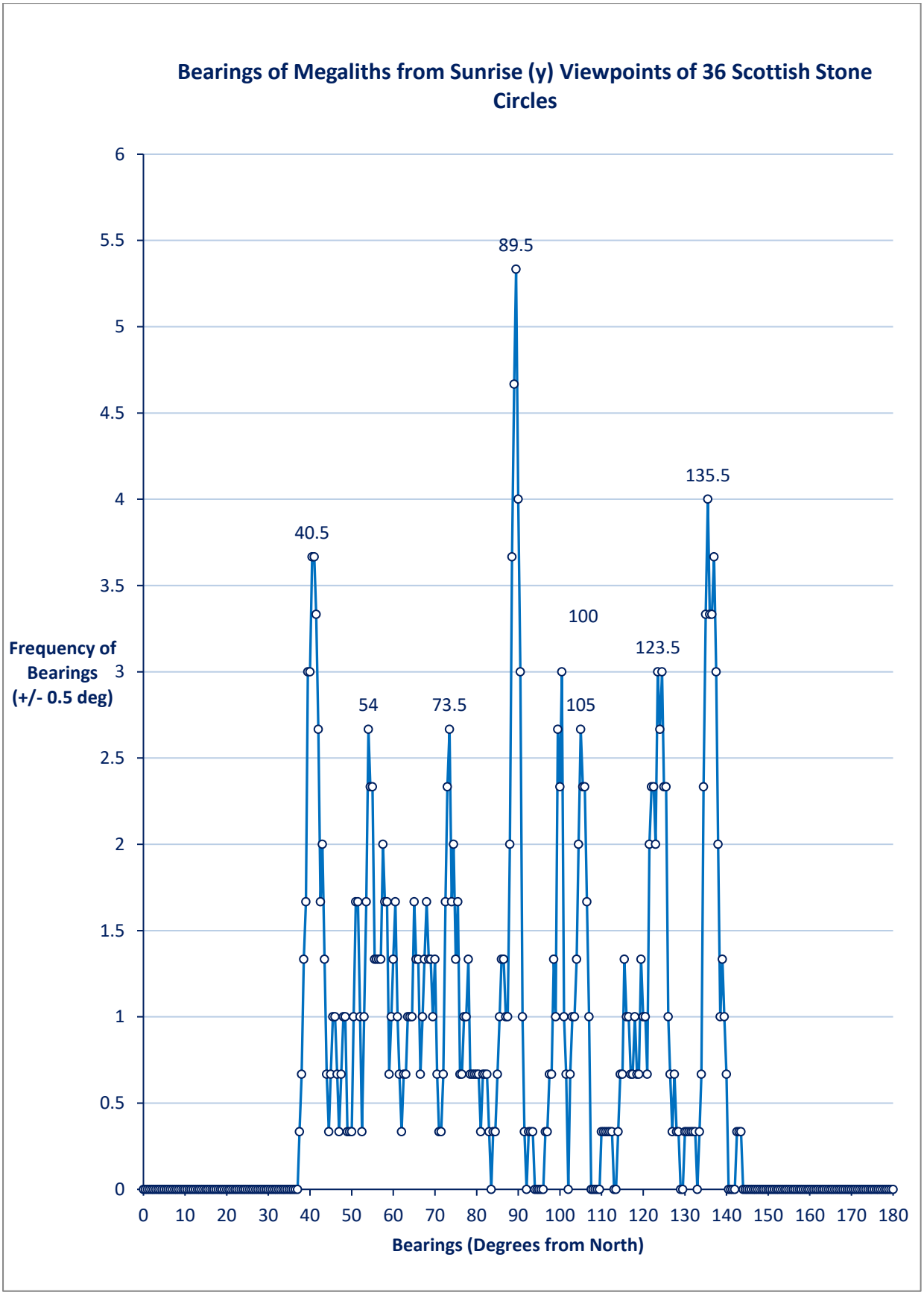
The bearings of the megaliths from viewpoints x and y are tabulated in Table 2 for each of the selected 36 Scottish stone circles. The positions determined for the viewpoints x and y and the alignments to the megaliths from those viewpoints are shown for each of the 36 stone circles in Appendix II.

Stone Circle	Alignments (degrees)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sunhoney	41.5	48	62	75	88	101	117.5	130.5	139	222.5	240.5	254	270.5	287.5	302.5	319.5				
Loanhead Of Daviot	43	56.5	87	104.5	123	139.5	223	235	253	271.5	288	308	318							
Aquorthies Kingausie	39	51.5	58	69.5	76.5	90	100	116	132	135.5	222	235	254.5	273	288	310.5	315	319.5		
Drannandow	40.5	51.5	73	79.5	89.5	99.5	124.5	136.5	221	244	258	290	304	318						
River Ness	43	54	78.5	105.5	124.5	137	222	232.5	250	268.5	289.5	310.5	331							
Blindwells	41	56.5	73.5	88.5	121.5	135	225.5	240	254.5	291	306.5	313	326							
Colen	38	54.5	63.5	74	91	99	116	135	213	225	244.5	270	291.5	295.5	307	320.5				
Leys of Marlee	41.5	54.5	70	90.5	119	134	221.5	248	271.5	301	318.5									
Loch Bule	58	63	73	90	105	123.5	138	219	237.5	258.5	272	291.5	308	319						
Aviemore	60.5	89	103	121.5	137	222.5	231	242	270	320										
Clava	41.5	50.5	59.5	68	97	113.5	124	136.5	225.5	235	244	257	269.5	282	294.5	303.5	313	320		
Little Urchany	42	89.5	116	136	221.5	253.5	287													
Urquhart	76	90	106	122	223	228	268.5	303												
Milltown	54.5	67.5	88.5	125.5	223	235	296	316.5	321											
Carnousie	41	46	53.5	60.5	124.5	136.5	223	237.5	248	254.5	260.5	271.5	278	290.5	296	299.5	301.5	320.5		
Raedykes South	40	59	66	74.5	82.5	112	125.5	136.5	138	222	237.5	243	250.5	288.5	298	312.5	320			
Tomnaverie	41	54.5	65	74.5	86.5	100	124.5	139	221	236	256	266	274	285.5	305	320				
Auchnagorth	39	55.5	68.5	89	98.5	121.5	135.5	220	236	252.5	256	271	317.5							
Tarland	41	73.5	100	117	223.5	231	286.5	304.5												
Midmar	40	60.5	77.5	106.5	123.5	136.5	221.5	240.5	255	290.5	292	307								
Yonder Bognie	40	66.5	90	99	105.5	118.5	124.5	134.5	221.5	239.5	256	287	320.5							
Castle Fraser	42	53.5	85	103.5	122	138	224	235.5	242.5	258.5	271	289	305							
Clune Wood	41	55	58	66	82.5	86	101	123.5	137.5	221	229	235.5	271	289.5	321					
Esslie the Greater	40	54	65.5	68	72.5	78	89	120.5	125	135.5	229.5	237	239.5	254	269.5	282.5	288.5	306	321	
Shianbank	43.5	57	75	89	105	122.5	143	221.5	235	260	289.5	303	321							
Loch Mannoch	38.5	45.5	58.5	73.5	90	106.5	120.5	135.5	221	236.5	252.5	270	287	302	316	323				
Cullerlie	39.5	50	67	88.5	106	124	135.5	224	233	250	268.5	288	306.5	320.5						
Tyrebagger	41.5	52	71	86.5	100	111	124.5	137.5	221	235.5	251.5	269.5	286	306	321					
Wamphray	42.5	46.5	57	86.5	90.5	100	220.5	267	279	291.5	298	317								
Druid Temple	39	48	56	68	74	80.5	83.5	88.5	93	103.5	122.5	138	232.5	236	258	272	286	304	323	
Mains of Gask	48	58.5	73.5	89.5	104.5	122	136	221.5	239	270.5	308.5	318.5								
Farr West	40	51	65	70	80	100.5	120	137	222	238.5	277.5	294.5	307	319						
Fountain Hill	41	61	88.5	128	135	234	242	249	259.5	269	281.5	305.5	321.5							
Esslie the Lesser	43	87.5	105	123	135	222	236	255	271											
Aquorthies Manar	45.5	53	64	78	90	103	115.5	127	137.5	220	228	235	255	271	285.5	300				
Ardlair	55.5	72	97	106.5	126	137.5	225.5	235.5	253.5	272	307.5	310.5	318.5							

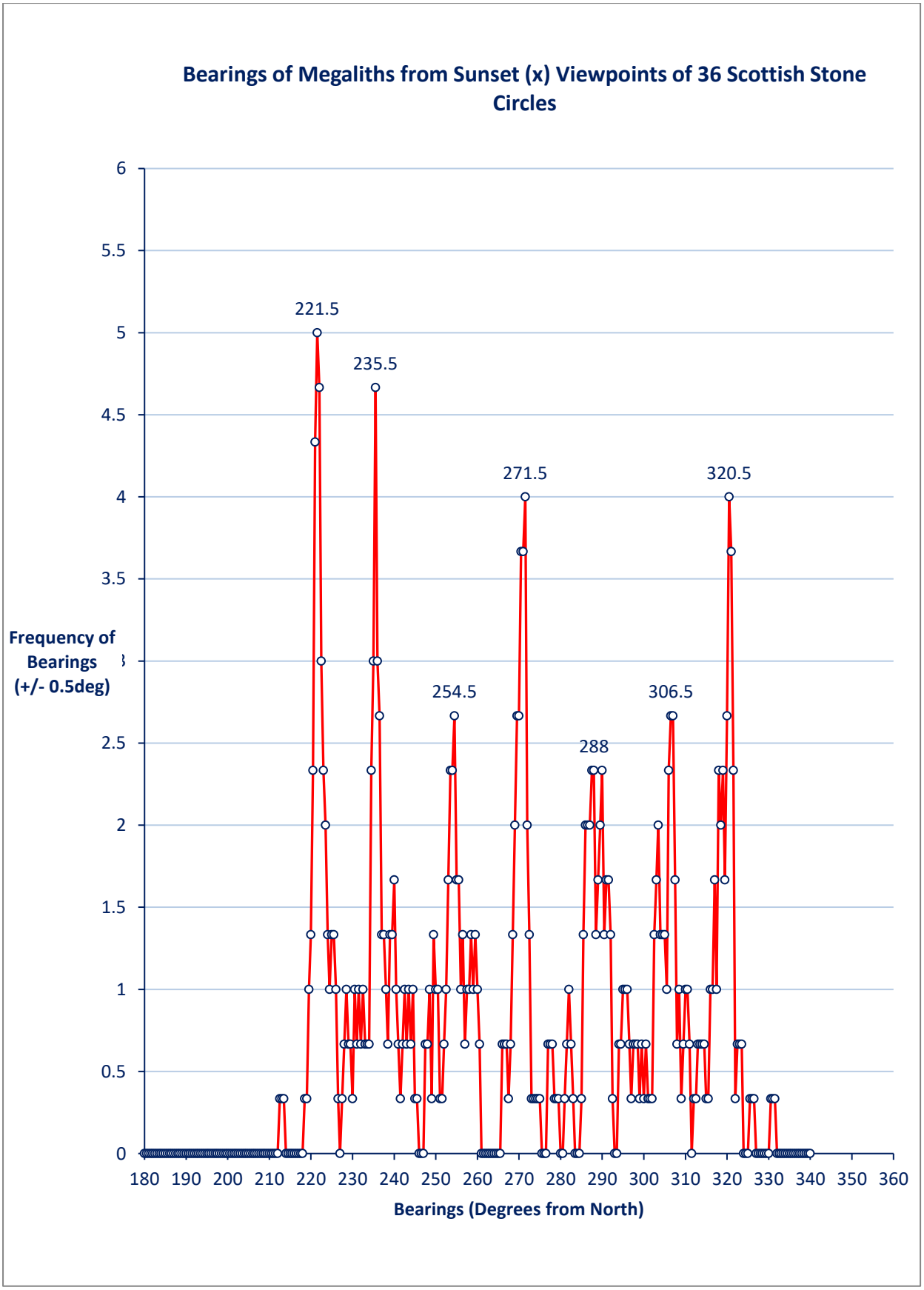
Table 2 Measured bearings of each of the megaliths for 36 stone circles from the "best-fit" proposed sunset viewing position x and sunrise viewing position y. Sunrise alignments 38 -143^0 and sunset 216- 323^0.

As the stones have a significant width, there is some latitude with the angle measured through the centre of the stone where the Sun on the horizon could be considered to be aligned with the stone depending on the dimensions of the stone, its shape, orientation and distance from the viewpoint. There is also the likelihood that some stones have toppled or been moved either intentionally for reuse or through natural processes involving ground movement and the effects of thousands of years of exposure to the effects of the wind, rain and ice. Where a stone has toppled, a point on the perimeter closest to where the fallen stone now lies was taken to be the original location of the stone and was used for alignment rather than the centre of the displaced fallen stone. If the stones were erected at different times or the stone circle used over a long time, there is the possibility that the stone positions for some stone circles may have been adjusted to take account of the gradually changing alignment of the Sun on different festival days, due to the precession of the equinoxes. In addition, there are the usual errors associated with the measurement of the stone circles in the field and subsequent drawing of plans and measurement of angles of alignment and other compound errors that should also be taken into account. There is the further consideration that the horizon was and is not flat in many locations and that the Sun set into, or rose from, an elevated feature such as a hill or mountain at a time that was either slightly later than the actual time of sunrise or earlier than the time of sunset in which case the topography of the particular landscape surrounding each stone circle should ideally also be taken into account as this also would affect the positioning of the megaliths. However, despite all these parameters that may introduce a degree of variability in the measured data, there are many stone circles in a reasonable state of preservation and the intention is to determine whether, despite the different sizes of the stone circles, there is a general common pattern of megalith placement around the circumference of the stone circles which can still be observed.

The frequency of occurrence of the different megalith bearings relative to each viewpoint x and y, for all 36 stone circles was analysed to determine whether a common pattern of bearings of alignment emerged from the angle data suggesting that the megaliths were erected in preferred positions which corresponded to alignments with the Sun on the horizon on particular days. The bearings of the stones relative to the viewpoints were plotted on two graphs as rolling averages plus or minus half a degree. Graph 1 shows the bearings of megaliths from viewpoint y corresponding to sunrise alignments and Graph 2 shows the bearings of megaliths from viewpoint x corresponding to sunset alignments.



Graph 1 Frequency of occurrence of megalith bearings from viewpoint y relative to North. Megaliths are those of the 36 selected Scottish stone circles identified in Table 2.



Graph 2 Frequency of occurrence of megalith bearings from viewpoint x relative to North. Megaliths are those of the 36 selected Scottish stone circles identified in Table 2.

By plotting the bearings of megaliths relative to the viewpoints of the 36 Scottish stone circles, it is striking that the graphs reveal a series of discreet peaks. The peaks appear to occur within quite narrow angle bands close to the angular width of the stones that suggests the stones were positioned deliberately to align with certain angles from the proposed peripheral viewpoints. There appear to be eight major peaks for megaliths positioned around the eastern perimeter of the circles and seven peaks positioned around the western perimeter. Two peaks in Graph 1, at 100 degrees and 105 degrees appear close together but have the appearance of representing two distinct bearings (marked as two stones "e" in diagram 6) and it appears that on further examination of the circles most of the circles (around 80%) have a megalith associated with one or the other (13 circles have a megalith on a bearing of 100 degrees and 16 have a megalith on a bearing of 105 degrees) except Yonder Bognie which has two megaliths, one aligned with each bearing. Given that the positions of the viewing points were determined by using the alignment of megaliths with the Sun on the horizon on the days of the solstices and equinoxes, three of the peaks can be readily accounted for on each graph. The peak bearings of 40.5˚, 89.5˚ and 135.5˚ in Graph 1 may relate to the sunrise bearings, to an error of about one degree, for the summer solstice (39.4˚), the spring and autumn equinoxes (88.2˚/89.3˚) and the winter solstice (136.7˚), and the peak bearings of 222.5˚, 271.5˚and 319.5˚ in Graph 2 may relate to the sunset bearings for the winter solstice (223.2˚), the spring and autumn equinox (271.0˚/271.6˚) and the summer solstice (320.6˚). This leaves four additional bearing peaks in the sunset graph and five additional peaks in the sunrise graph to account for.

As the positions of the viewpoints were established using the alignment of the Sun at sunrise and sunset on the days of the solstices and equinoxes, with the megaliths, we might expect the preferred angles of alignment revealed by the peaks to also indicate days when the Sun was aligned with the megaliths on the horizon. The archaeo-astronomy program “SkyMap Pro II” was used to determine which days corresponded to the preferred alignments as indicated by the peak bearing values on Graphs 1 and 2, taking into account both the latitude of the stone circle and the estimated date of its construction. The rising Sun moves along the arc of the horizon from a position north-east at sunrise at the summer solstice to a position in the south-east at the winter solstice and then returns northwards as the year progresses to once again turn South after the next summer solstice, this means that although the position of the Sun on the horizon marks the day of the year, there are, with the exceptions of the solstices, two days that correspond to each alignment one before winter and one after, for instance when the Sun appears more or less due East at sunrise and due West at sunset this marks both the day of the spring equinox and that of the autumn equinox. Each alignment bearing can therefore be associated with two possible dates that will have completely different night skies. Whilst the northern and southern limits of the Sun on the horizon marking the solstices and the East-West alignments of sunrise and sunset at the equinoxes are

obvious solar markers in defining the seasons of the year, the significance of the other stone alignments between positions marking the extremes of the Suns positions is not immediately obvious.

Further evidence that the stone circle was designed as a calendrical device would be gained if the days suggested by the alignment of these other megaliths and the rising and setting Sun could be shown to have a significance beyond a date, and that some important observable event occurred on these days. Given that the stone circles were constructed over a range of hundreds of miles it is likely that any event that was visible to all the people must have been located in the sky and the only objects other than the Sun which have a predictable and constant cyclical annual appearance in the sky are the stars and their constellations. If the megaliths marked certain days through their alignment with the Sun at sunrise and sunset then on these days at night time then perhaps a bright star occupied an important position either on the horizon or aligned due South or aligned with one of the other cardinal points. An archaeo-astronomy program calculates the position of stars at a particular time and location and allows us to view the night skies our ancient ancestors observed at the time the stone circles were being used. Unfortunately, the date of construction of the stone circles is uncertain and as the stars appear to revolve around the celestial pole, the pattern of stars changes constantly throughout the night from dusk to the following dawn as the Earth rotates about its axis. In other words, for the stars to occupy a position of significance other than on the horizon, the time of night has to be known and without the aid of a clock the only times that can act as a reliable marker to define the position of a star, other than the times when they rise and set, are the times when those stars first become visible in the darkening night sky at dusk or the time when they just disappear in the lightening night sky at dawn. The time when the brightest stars in the sky are just visible at dawn and dusk is termed "Civil Twilight" in astronomy, this refers to two specific times when the Sun lies six degrees below the horizon termed Start of Civil Twilight just before dawn and End of Civil Twilight at dusk. At civil twilight the sky is just dark enough to see the brightest stars in the sky and at the End of Civil Twilight these bright stars are the first to be switched on and conversely at Start of Civil Twilight before the Sun rises the brightest stars are the last stars to just disappear as the skies lighten. Civil Twilight together with an alignment due South in the sky therefore could be used as a time reference to mark the position of the brightest stars including the circumpolar stars which by definition do not set below the horizon. The day when an important bright star precisely aligned due South at the End of Civil Twilight might be celebrated as a festival day dedicated to a deity associated with that star.

Stellar Alignments due South at Civil Twilight on Festival Days

The day indicated by the alignment of the Sun on the horizon with a megalith, when viewed from either the eastern sunset viewpoint or western sunrise viewpoint in most cases coincided with the day when a very bright star was aligned precisely due South at Civil Twilight. An example of such a stellar alignment, in this case Spica, the brightest star in Virgo, perhaps representing a festival day dedicated to a goddess is shown below. This festival day alignment happens to coincide with the alignment of two stones (i and c) and the rising Sun when viewed from viewpoint y on the day of the festival celebrating the Goddess at the beginning of May.

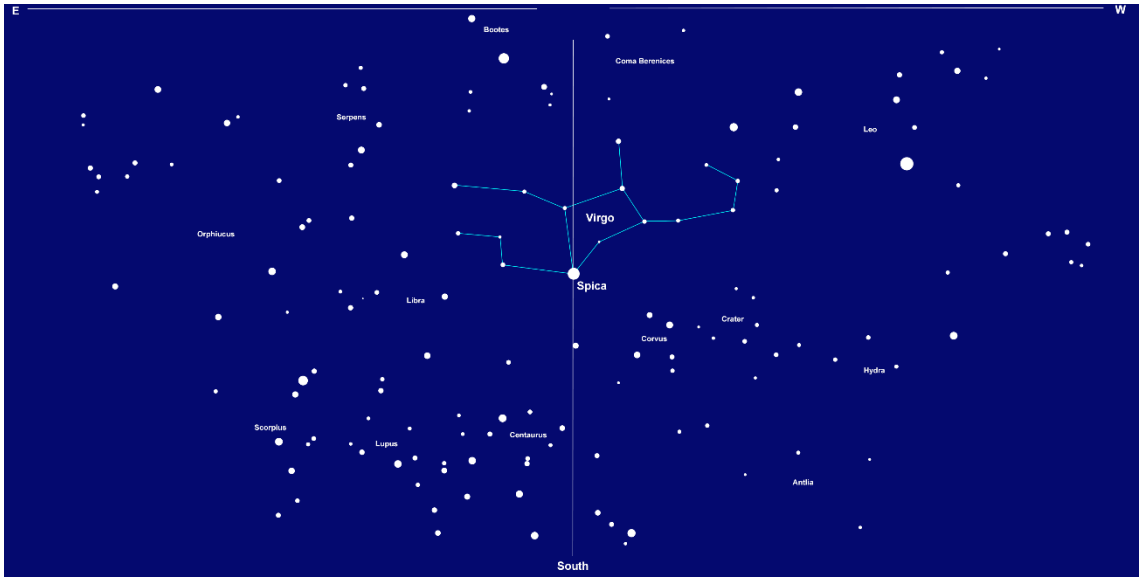


Image to illustrate the precise alignment of Spica the brightest star in the constellation of Virgo due South at the moment of End of Civil Twilight on May 8th 3000BC, Aberdeenshire, Scotland. Of the other stars shown only the brightest would be visible at Civil Twilight such as Alpha Bootes, Regulus in Leo, Alphard in Hydra, the other stars only becoming visible as the skies darkened as the Sun set further below the horizon.

Candidate Stars that could have been used for Alignment purposes

Only the brightest stars would be visible at Civil Twilight and it would also make sense, given the extensive nature of constellations, that the brightest star in the constellations would have been regarded as representing the stellar deities for alignment purposes to indicate the day of celebration of the festival dedicated to the stellar deity associated with the constellation.

The fifteen brightest stars together with the bright stars Alphard in the constellation of Hydra, Scheat in Pegasus, Deneb Algedi in Capricorn and Alpha Comae Berenices in Coma Berenices, were examined alongside the star clusters known as the Pleiades in Taurus, popularly called the Seven Sisters and Mel-111 in Coma Berenices proposed by the author to represent the Nine Maidens of popular mythology, were chosen to determine the days on which they aligned due South at Civil Twilight.

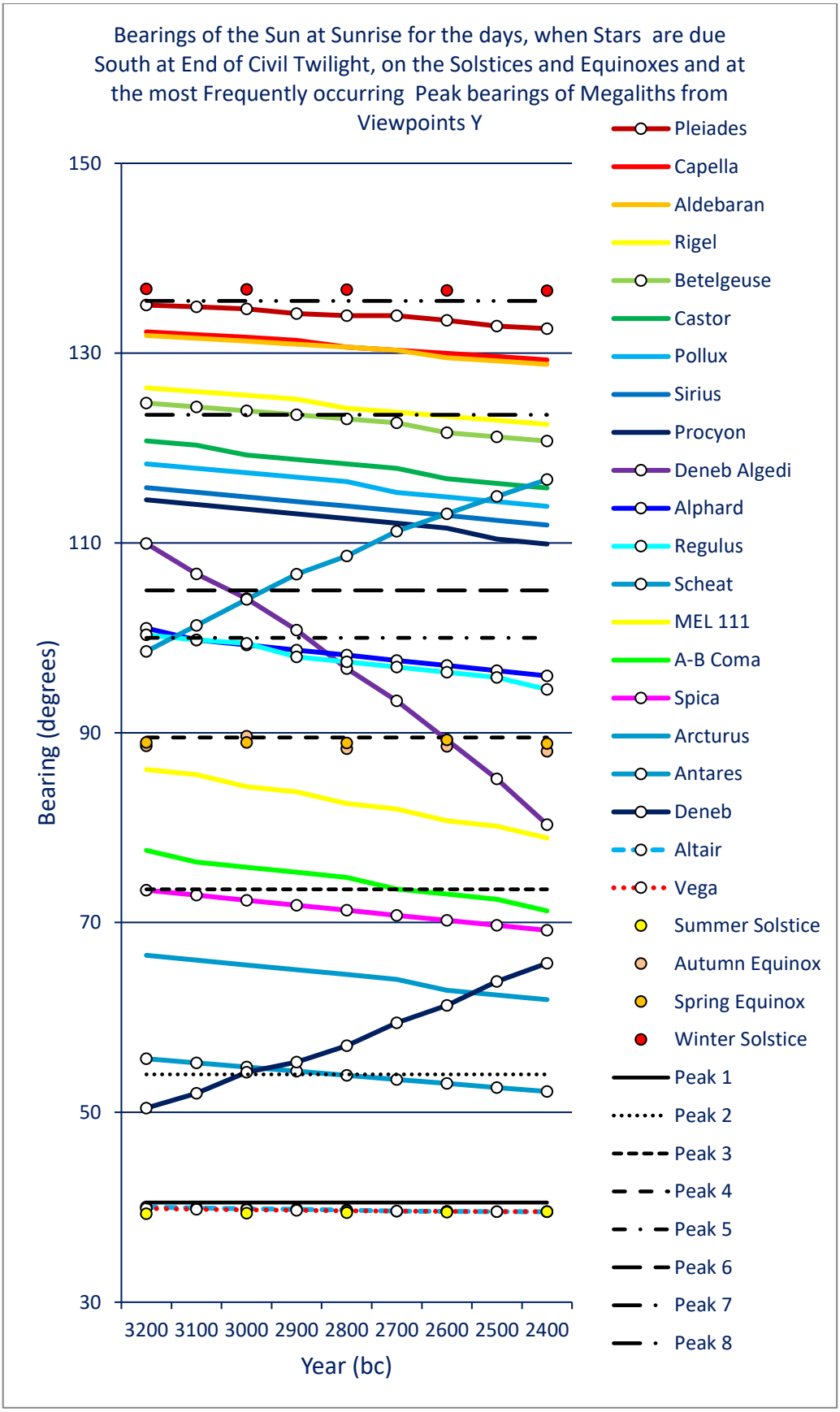
Star	Constellation	Visual Magnitude
Sirius	Canis Major	-1.44
Arcturus	Bootes	-0.05
Vega	Lyra	-0.02
Capella	Auriga	0.08
Rigel	Orion	0.17
Procyon	Canis Minor	0.40
Betelgeuse	Orion	0.0-1.3
Altair	Aquila	0.76
Aldebaran	Taurus	0.75-0.95
Spica	Virgo	0.95
Antares	Scorpio	0.88-1.16
Pollux	Gemini	1.16
Deneb	Cygnus	1.21
Regulus	Leo	1.36
Castor	Gemini	1.58
Alphard	Hydra	1.99
Scheat	Pegasus	2.31
Deneb Algedi	Capricorn	2.85
Alpha Comae Berenices	Coma Berenices	4.3
Pleiades	Taurus	1.2
MEL-111	Coma Berenices	1.8

Table 3 Brightest stars and star clusters selected for determination of days of alignment due South at Civil Twilight.

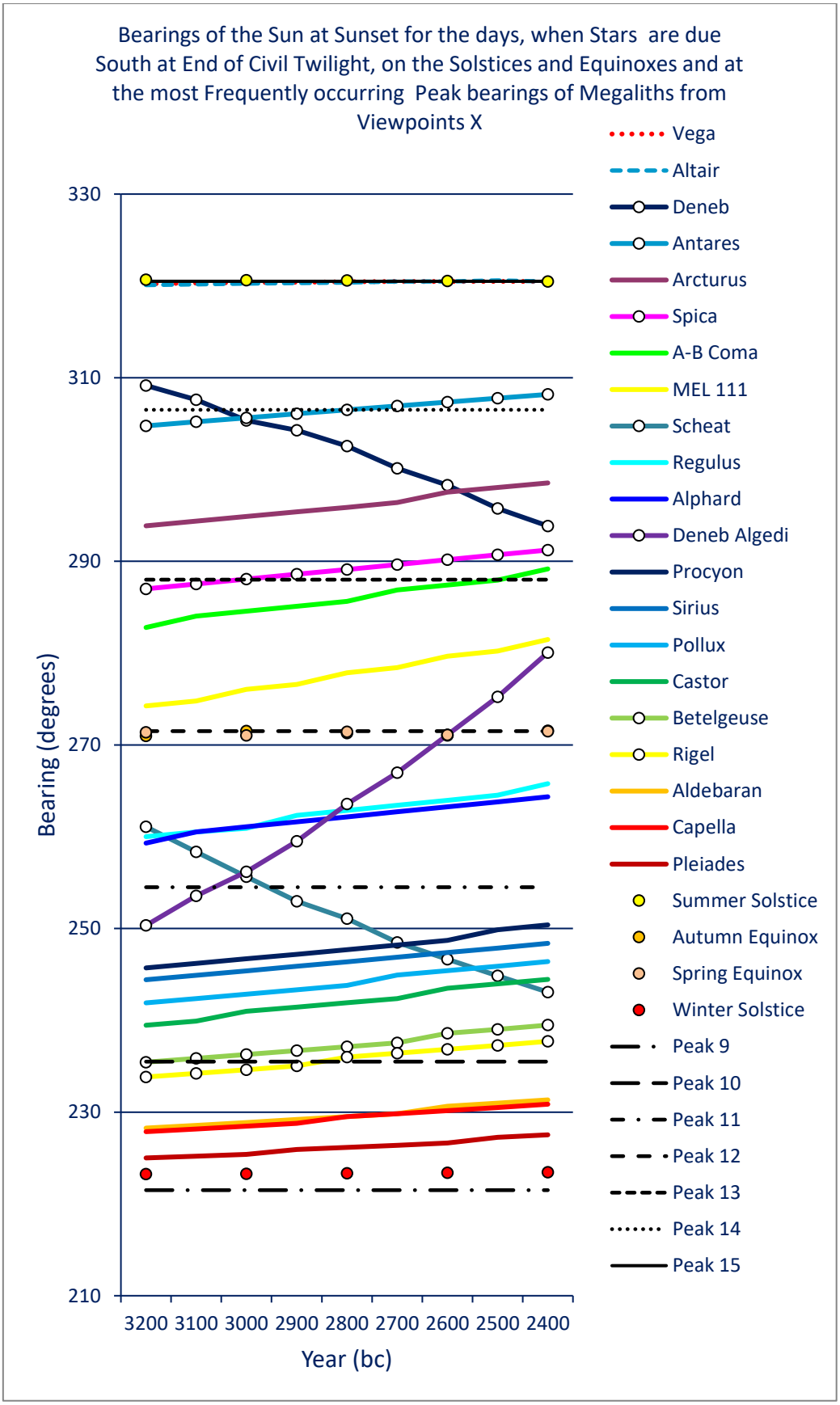
The days on which each of the twenty stars and star clusters aligned due South at Start of Civil twilight and End of Civil twilight were determined for each century between 3200BC-2400BC. The bearings of the Sun on the horizon at sunrise and sunset were then determined for each of these days. These archaeo-astronomical alignments were determined using the SkyMap Pro II program. The latitude and longitude chosen were those of Aberdeen 57˚ 9' 0" North and 2˚ 4' 48" West at an altitude of 10 metres. The day closest to a due South alignment for each star at Civil Twilight was determined for the chosen year and the time of sunrise and sunset was then calculated for that day and then used to find the azimuth of the Sun. In this way the bearings of the Sun on the horizon on the days when the selected bright stars were aligned due South in the sky at Civil Twilight at both dawn and dusk were determined for comparison with the alignment bearing peaks revealed in Graphs 1 and 2.

Graphs 3-6 were plotted to show the bearing of the Sun at sunrise and sunset for each century between 3200BC and 2400BC when each of the 19 stars and star clusters aligned due South at End of Civil Twilight at dusk and Start of Civil Twilight at dawn. The bearings identified as peaks on Graphs 1 and 2 identified as the most frequently occurring bearings

of the megaliths of the 36 stone circles relative to the proposed viewing positions x and y were also plotted on these graphs to determine if any of the days of star alignment due South at Civil Twilight coincided with the alignment of megaliths with the position of the Sun on the horizon on those days and for which years these coinciding alignments occurred.


Bearings of the Sun at Sunrise for the days, when Stars are due South at End of Civil Twilight, on the Solstices and Equinoxes and at the most Frequently occurring Peak bearings of Megaliths from Viewpoints Y
Bearing (degrees)
150
130
110
90
70
50
30
3200 3100 3000 2900 2800 2700 2600 2500 2400
Year (bc)
Pleiades
Capella
Aldebaran
Rigel
Betelgeuse
Castor
Pollux
Sirius
Procyon
Deneb Algedi
Alphard
Regulus
Scheat
MEL 111
A-B Coma
Spica
Arcturus
Antares
Deneb
Altair
Vega
Summer Solstice
Autumn Equinox
Spring Equinox
Winter Solstice
Peak 1
Peak 2
Peak 3
Peak 4
Peak 5
Peak 6
Peak 7
Peak 8

Graph 3


Bearings of the Sun at Sunset for the days, when Stars are due South at End of Civil Twilight, on the Solstices and Equinoxes and at the most Frequently occurring Peak bearings of Megaliths from Viewpoints X
Bearing (degrees)
330
310
290
270
250
230
210
3200 3100 3000 2900 2800 2700 2600 2500 2400
Year (bc)
Vega
Altair
Deneb
Antares
Arcturus
Spica
A-B Coma
MEL 111
Scheat
Regulus
Alphard
Deneb Algedi
Procyon
Sirius
Pollux
Castor
Betelgeuse
Rigel
Aldebaran
Capella
Pleiades
Summer Solstice
Autumn Equinox
Spring Equinox
Winter Solstice
Peak 9
Peak 10
Peak 11
Peak 12
Peak 13
Peak 14
Peak 15

Graph 4

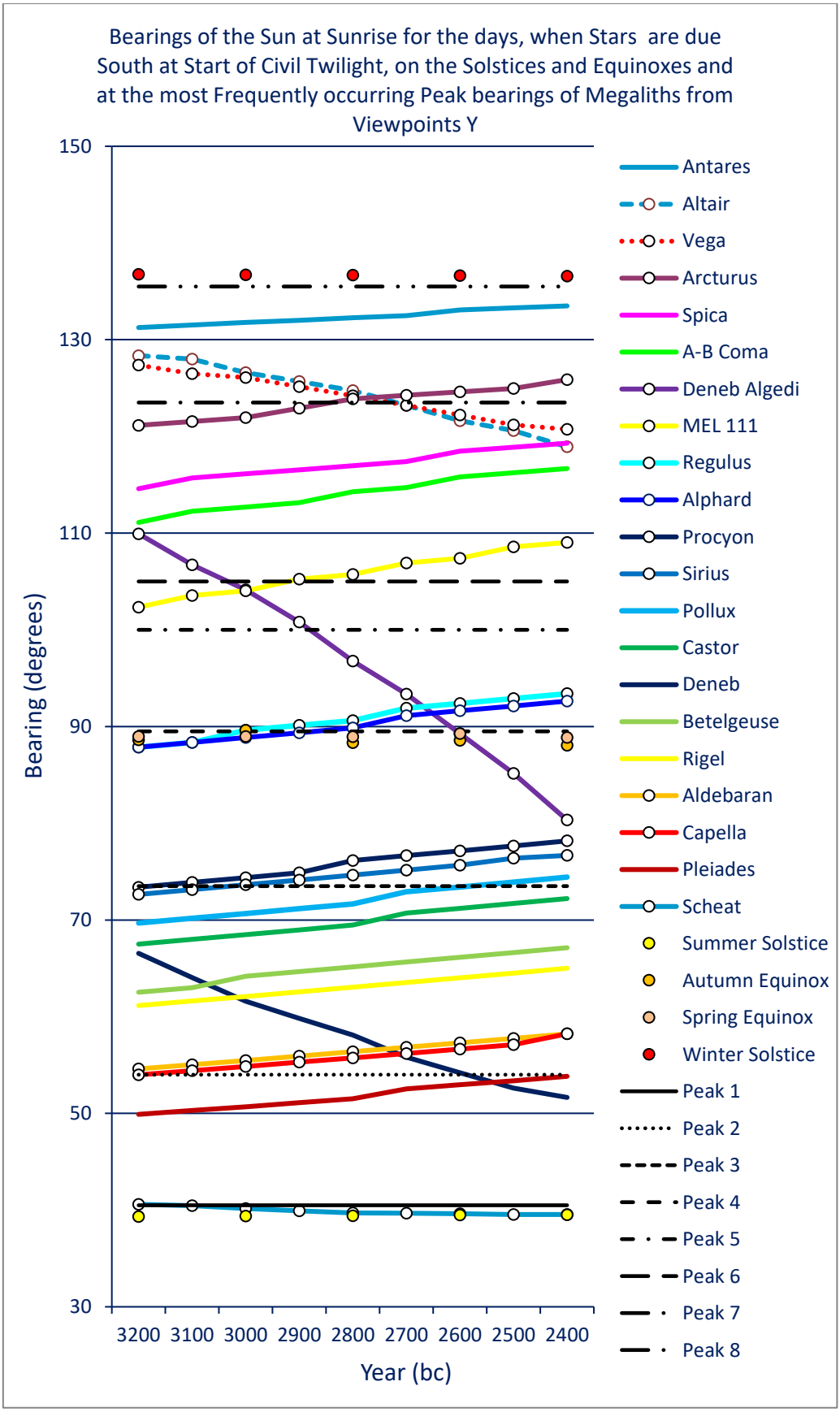
Graphs 3 and 4 show the bearings of the megaliths and the bearings of the Sun at sunrise and sunset on the days when the stars are aligned due South at End of Civil Twilight indicate that the following days can be consistently indicated by the alignment of the Sun on the horizon and the megaliths when viewed from X and Y for the years around 3000 BC. The curves for stars that intersect or closely approach the megalith alignment bearings are marked on the graphs with open circle markers.

Alignment (Stone)	Day indicated by Sunrise alignment	Alignment (Stone)	Day indicated by Sunset alignment
1 (a)	Summer Solstice Altair Vega	15 (c)	Summer Solstice Altair Vega
2 (b)	Deneb Antares	14 (b)	Deneb Antares
3 (c)	Spica	13 (a)	Spica
4 (d)	Autumn and Spring Equinoxes	12 (i)	Autumn and Spring Equinoxes
5 (e)	Alphard Regulus		
6	Scheat Deneb Algedi	11 (h)	Scheat Deneb Algedi
7 (f)	Betelgeuse	10 (g)	Betelgeuse Rigel
8 (g)	Winter Solstice Pleiades	9 (f)	Winter Solstice

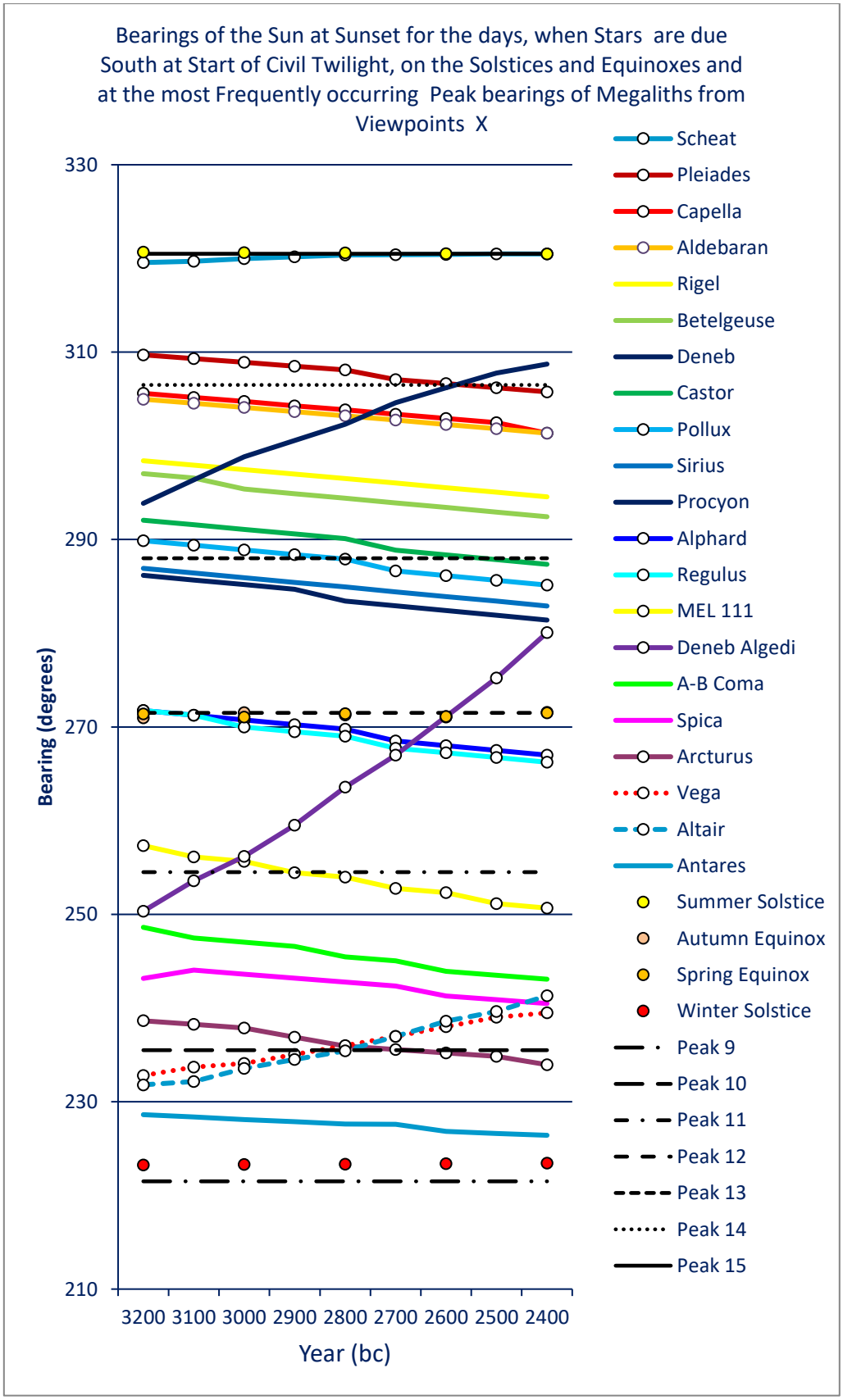
Table 4 Stars aligned due South at the End of Civil Twilight and solar festival days indicated by alignment of the Sun on the horizon with the megaliths

The alignments of the megaliths with the Sun on the horizon present a symmetrical pattern where the megaliths on either side of the circle align with the rising Sun on one side and the setting Sun on the other and appear to indicate the same stellar alignment

days. The alignment of Altair and Vega coincides with the time of the summer solstice, the other stars that appear to be important in their own right are Betelgeuse in Orion, Spica in Virgo, Scheat in Pegasus (sitting directly above the Circlet of Pisces), Deneb in Cygnus, Deneb Algedi in Capricorn and Antares in Scorpio. Stones **a**, **b**, **c**, **f** and **g** are each used for two alignments. Stone **a** for alignments 1 and 13, stone **b** for alignments 2 and 14, stone **c** for alignments 3 and 15 stone **f** for alignments 7 and 9 and stone **g** for alignments 8 and 10. The positioning of the megaliths allows the days when these five stars are aligned due South at Civil twilight to be indicated by both the alignment of the rising Sun with a megalith on the eastern side of the circle from the viewpoint y on the West side and another megalith on the western side of the circle at sunset when viewed from viewpoint x on the eastern side.


Bearings of the Sun at Sunrise for the days, when Stars are due South at Start of Civil Twilight, on the Solstices and Equinoxes and at the most Frequently occurring Peak bearings of Megaliths from Viewpoints Y
Bearing (degrees)
150
130
110
90
70
50
30
3200 3100 3000 2900 2800 2700 2600 2500 2400
Year (bc)
Antares
Altair
Vega
Arcturus
Spica
A-B Coma
Deneb Algedi
MEL 111
Regulus
Alphard
Procyon
Sirius
Pollux
Castor
Deneb
Betelgeuse
Rigel
Aldebaran
Capella
Pleiades
Scheat
Summer Solstice
Autumn Equinox
Spring Equinox
Winter Solstice
Peak 1
Peak 2
Peak 3
Peak 4
Peak 5
Peak 6
Peak 7
Peak 8

Graph 5


Bearings of the Sun at Sunset for the days, when Stars are due South at Start of Civil Twilight, on the Solstices and Equinoxes and at the most Frequently occurring Peak bearings of Megaliths from Viewpoints X
Bearing (degrees)
330
310
290
270
250
230
210
3200 3100 3000 2900 2800 2700 2600 2500 2400
Year (bc)
Scheat
Pleiades
Capella
Aldebaran
Rigel
Betelgeuse
Deneb
Castor
Pollux
Sirius
Procyon
Alphard
Regulus
MEL 111
Deneb Algedi
A-B Coma
Spica
Arcturus
Vega
Altair
Antares
Summer Solstice
Autumn Equinox
Spring Equinox
Winter Solstice
Peak 9
Peak 10
Peak 11
Peak 12
Peak 13
Peak 14
Peak 15

Graph 6

Graphs 5 and 6 show the most common megalith bearings together with the bearings of the Sun at sunrise and sunset on the days when the brightest stars are aligned due South at Start of Civil Twilight. The positions where the curves for the bearings of megaliths and stars intersect or come close to coinciding reveal stellar days that could have been marked by alignment of the Sun on the horizon with those megaliths. Each of the megalithic bearings viewed from viewpoints x and y are seen to coincide with either a solar festival and/or a day when one of the brightest stars is positioned due South at civil twilight. The following days can be indicated by the alignment of the Sun on the horizon and the megaliths when viewed from x at sunset and y at sunrise.

Alignment (Stone)	Day indicated by Sunrise alignment	Alignment (Stone)	Day indicated by Sunset alignment
1 (a)	Summer Solstice Scheat	15 (c)	Summer Solstice Scheat
2 (b)	Capella Aldebaran	14 (b)	Capella Aldebaran
3 (c)	Procyon Sirius	13 (a)	Pollux
4 (d)	Autumn and Spring Equinoxes Alphard Regulus	12 (i)	Autumn and Spring Equinoxes Alphard Regulus
5 (e) 6	- Mel-111 Deneb Algedi	11 (h)	Mel-111 Deneb Algedi
7 (f)	Arcturus	10 (g)	Arcturus Altair Vega
8 (g)	Winter Solstice	9 (f)	Winter Solstice

Table 5 Stars aligned due South at Start of Civil Twilight on days indicated by alignment of the Sun with megaliths

The alignment of Scheat due South at the Start of Civil Twilight coincides with the summer solstice whilst the alignments of Alphard and Regulus due South at the Start of Civil Twilight coincides with the day of the autumn equinox whilst Scheat is due South at the Start of Civil Twilight on the summer solstice. The stars that appear to be indicated by the alignment of the Sun at sunrise and sunset with the megaliths are Capella, Aldebaran, Pollux, Sirius, Arcturus, Deneb Algedi and the star cluster Mel-111. The only star that is

indicated by alignments at start of civil twilight (Table 6) and end of civil twilight (Table 4) is Deneb Algedi in Capricorn which may be evidence of this constellation's overarching importance in the pantheon of Pictish deities. The marking of days when the brightest stars are aligned due South at Civil Twilight is more evidence that the peripheral viewing points might have been used to indicate important days in the Neolithic calendar. However, it would be even more persuasive if the solar and stellar festival days provided a calendar that had a fairly regular distribution of festival days throughout the year in other words a calendar that appeared to be planned and unlikely to have resulted from chance.

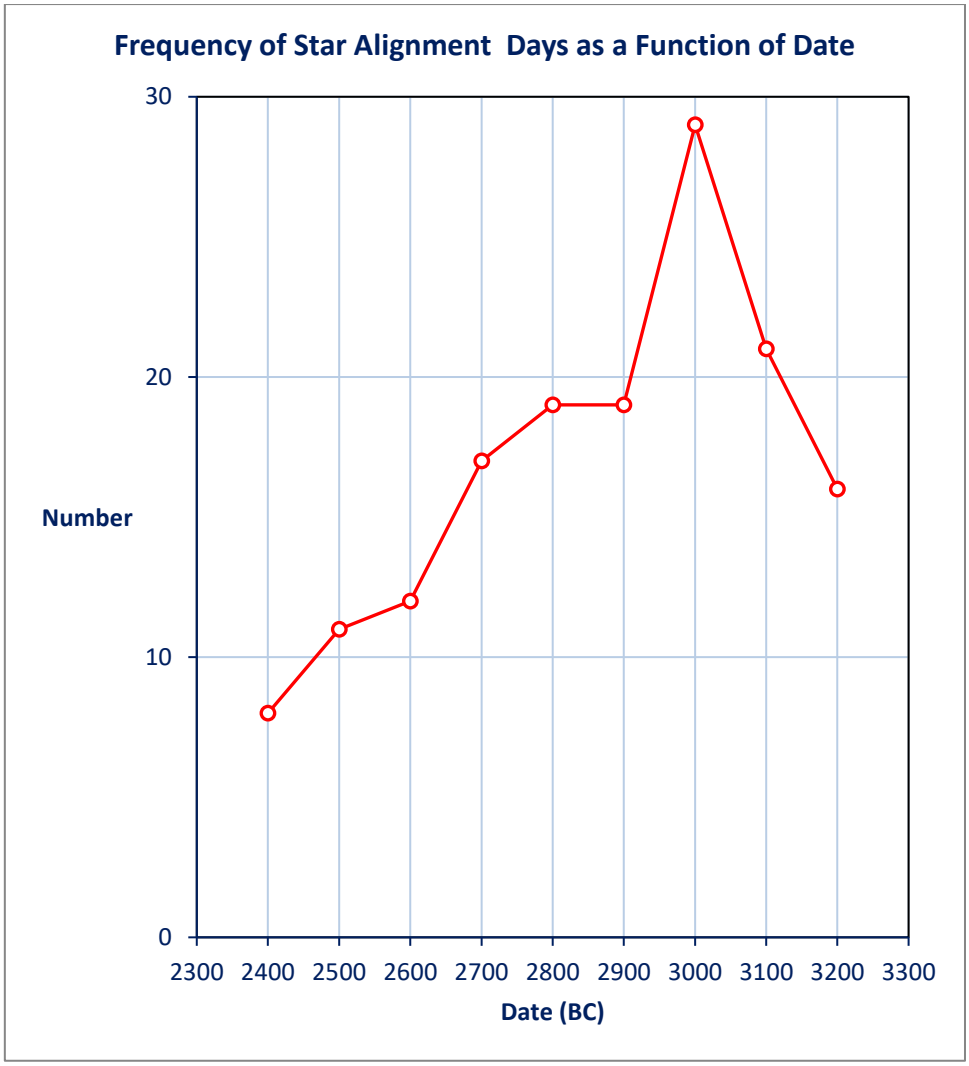
Date of Stone Circle Use

The bearings of the megaliths relative to the viewing positions x and y coincide with the Sun on the horizon at sunset and sunrise respectively on the days of the equinoxes and solstices and the days when the brightest stars and an important star cluster are aligned due South at the End of Civil Twilight and the Start of Civil Twilight. The closest fit of bearings of the megaliths and days of alignment of the stars occurs around 3000BC. There is a high degree of symmetry of the alignments with the seven megalith alignments on either side, East and West, of the circle marking the same days so that the festival days can be determined either at sunrise or sunset. Altair and Vega are close to due South on the day of the summer solstice whereas the spring and autumn equinoxes and the winter solstice appear not to have any of the brightest stars aligned due South at the End of Civil Twilight on these days. Of the stars selected some are due South at End of Civil Twilight on days that only vary within 3-5 degrees over the 800 year period whilst others such as Deneb, Scheat and Deneb Algedi are due South on days that vary by as much as 15 degrees ,18 degrees and over 29 degrees respectively over the 800 year period selected, as illustrated by the steep gradients of their curves in Graphs 3-6. As such Scheat, Deneb and Deneb Algedi are good markers of the likely date of construction of the stone circles as their curves intersect the megalith bearing curves at a steep angle and in each case the date corresponding to the intersection is approximately 3000BC. These curves give us further information in determining whether the position of the stones could have been adjusted with the passing centuries to realign the stones with the changing days associated with the stellar alignment at civil twilight and it seems unlikely that the stone circles could have been useful in marking days when these three stars were due South at Civil Twilight for more than about a century, furthermore the opportunity to adjust the position of the stones to counteract the shifting alignments is not possible because so many of the megaliths were used to indicate two alignment days and in most cases the movement of the stone in one direction to aid alignment of one festival day would be at the expense of the alignment of the stone on the other festival day. (See Appendix III). In other words, once the stones were positioned to indicate an alignment the useful life of the stone circle was set as the star positions slowly moved relative to each other over the

following centuries and the alignments no longer held true and could not be adjusted to compensate for precession.

Alignment	Peak (Bearing)	Stone	End of Civil Twilight Alignment		Start of Civil Twilight Alignment	
			Star	Year	Star	Year
Sunrise Alignments	1 040.5	a	Summer solstice Altair Vega	2400BC 3200-2400BC 3200-2400BC	Summer solstice Scheat	2400BC 3200-2400BC
	2 054.0	b	Deneb Antares	3000BC 3000-2600BC	Capella Aldebaran Deneb Pleiades	3200-3000BC 3200BC 2600BC 2500-2400BC
	3 073.5	c	Spica Alpha Comae	3200-3100BC 2700-2600BC	Pollux Sirius Procyon	2700-2400BC 3200-2900BC 3200-3000BC
	4 089.5	d	Autumn Equinox Spring Equinox	3200-2600BC 3200-2400BC	Autumn Equinox Spring Equinox Alphard Regulus	3200-2600BC 3200-2400BC 3000-2800BC 3000-2900BC
	5 100.0	e	Alphard Regulus	3100-3000BC 3200-3000BC	Deneb Algedi	2900BC
	6 105.0		Scheat	3000BC	Mel-111 Deneb Algedi	3000-2800BC 3000BC
	7 123.5	f	Betelgeuse Rigel	3100-2700BC 2800-2500BC	Arcturus Vega Altair	2700BC 2800-2700BC 2900-2700BC
	8 135.5	g	Pleiades Winter Solstice	3200-3000BC 2400BC	Winter solstice	2400BC
Sunset Alignments	9 222.5	f	Winter Solstice	3200-2400BC	Winter solstice	3200-2400BC
	10 235.5	g	Betelgeuse Rigel	3200-3000BC 3000-2700BC	Arcturus Vega Altair	2800-2500BC 2900-2800BC 2800BC
	11 255.5	h	Scheat	3000BC	Mel-111 Deneb Algedi	3100-3000BC 3000BC
	12 271.5	i	Autumn Equinox Spring Equinox	3200-2400BC 3200-2400BC	AutumnEquinox Spring Equinox Alphard Regulus	3200-2400BC 3200-2400BC 3200-3000BC 3200-3100BC
	13 288.5	a	Spica Alpha Comae	3100-2800BC 2500-2400BC	Pollux Castor	3100-2800BC 2700-2500BC
	14 304.5	b	Deneb Antares	3000-2900BC 3200-3100BC	Capella Aldebaran Pleiades Deneb	3100-2800BC 3200-2900BC 2800-2400BC 2700BC
	15 319.5	C	Summer Solstice	2400BC	Summer solstice Scheat	2400BC 3200-2400BC

Table 6 The alignments, megaliths and approximate best-fit years of alignment from Graphs 3-6



Graph 7 The frequency of occurrence of the bearings of the megaliths coinciding with the bearing (within one degree) of the Sun on the horizon on days when the brightest stars are aligned due South at Civil Twilight. Data is taken from Table 6. The stars referred to are Altair, Vega, Deneb, Antares, Spica, Alpha Comae, Alphard, Regulus, Scheat, Betelgeuse, Rigel, Pleiades, Aldebaran, Capella, Pollux, Sirius, Procyon, Deneb Algedi, Mel-111, Arcturus and Castor.

The date that most closely matches the alignment of megaliths with days of stellar alignments is 3000BC. This date appears to be the most likely period within about a century when the stone circles were erected or last used. There is more support for this being the date when the megaliths were positioned to align with the days of the stellar festivals when the days of alignment for Deneb, Scheat and Deneb Algedi are examined. The curves representing the bearing of the Sun on the horizon on the days when these three stars are aligned due South at Civil Twilight have the steepest gradient and gradients that are opposite in direction to those relating to the other selected stars. The fact that the gradients of these curves are steep minimises the time period when the megalith bearing coincides with the megalith bearing with the result that if these alignments were meant then they give the best indication of the date that the stone circles were last used to mark these proposed festival days.

Alignment (Peak)	Stone	Bearing from x and y relative to North	Star aligned due South End of Civil Twilight	Year when the alignment of the Sun at sunrise or sunset coincides with a megalith (within 1 degree)	Sun on the Horizon at
2	(b)	054.0	Deneb	3000BC	Sunrise
6	(e)	105.0	Scheat	3000BC	Sunrise
6	(e)	105.0	Deneb Algedi	3000BC	Sunrise
11	(h)	255.5	Scheat	3000BC	Sunset
11	(h)	255.5	Deneb Algedi	3000BC	Sunset
14	(b)	304.5	Deneb	3000-2900BC	Sunset

Table 7 Alignment peaks are from Graphs 1 and 2. Stone labels are those given in Diagram 4. Mean bearings are from Graphs 1 and 2. Years of alignment are calculated from Graphs 3, 4, 5 and 6 to within one degree of the Peak Megalith bearing.

Sun on the Horizon	Alignment Peak Bearing	Stone	End of Civil Twilight Alignment	Start of Civil Twilight Alignment
Sunrise	1 040.5	a	Summer solstice Altair Vega Deneb Algedi	Summer solstice Scheat
	2 054.0	b	Deneb Antares	Capella Aldebaran
	3 073.5	c	Spica	Sirius Procyon
	4 089.5	d	Autumn Equinox Spring Equinox	Autumn Equinox Spring Equinox Alphard Regulus
	5 100.0	e	Alphard Regulus	-
	6 105.0		Scheat	Deneb Algedi Mel-111
	7 123.5	f	Betelgeuse	Arcturus Vega Altair
	8 135.5	g	Winter Solstice	Winter solstice
Sunset	9 222.5	f	Winter Solstice	Winter solstice
	10 235.5	g	Betelgeuse Rigel	Arcturus Vega Altair
	11 255.5	h	Scheat	Deneb Algedi Mel-111
	12 271.5	i	Autumn Equinox Spring Equinox	AutumnEquinox Spring Equinox Alphard Regulus
	13 288.5	a	Spica	Pollux
	14 304.5	b	Deneb Antares	Capella Aldebaran
	15 319.5	c	Summer Solstice Deneb Algedi	Summer solstice Scheat

Table 8 shows stars that are aligned due South at the Start and End of Civil Twilight on the days when the megaliths align with the Sun at sunrise and sunset from the viewing points y and x respectively for 3000BC.

It is interesting that the fourteen brightest stars in the sky from Table 3 appear to be represented as markers of precise alignments in the stone circles and given the number of stars that could have been aligned from the same constellations provides further evidence that the positioning of the stones is likely to have been planned and that the constellations associated with the brightest stars played a very important role in the lives of the people who built the stone circles in their calendar and most likely in their belief system with a pantheon of stellar deities being identified with those constellations. Given the hypothesis that the alignment due South of stars at civil twilight marked stellar festival days, it is only the brightest stars that are visible at this time and could be used in this way, so the discovery of their alignment on the days marked by the alignment of the megaliths and the Sun on the horizon provides strong support for the proposal.

Alignment Event	Date (3000bc)
Winter Solstice	January 13th
Altair at Start of Civil Twilight Vega at Start of Civil Twilight Rigel at End of Civil Twilight Betelgeuse due South at End of Civil Twilight	February 17th February 18th February 19th February 21st
Deneb Algedi at Start of Civil Twilight Alphard at End of Civil Twilight Regulus at End of Civil Twilight	March 24th March 30th March 31st
Spring equinox	April 14th
Spica due South at End of Civil Twilight	May 8th
Antares due South at End of Civil Twilight	June 4th
Scheat at Start of Civil Twilight Altair at End of Civil Twilight Vega at End of Civil Twilight Summer solstice Deneb Algedi at End of Civil Twilight	July 9th July 11th July 12th July 17th July 26th
Deneb due South at End of Civil Twilight Capella due South at Start of Civil Twilight Aldebaran South at Start of Civil Twilight	August 29th August 30th August 31st
Pollux due South at Start of Civil Twilight Sirius South at start of Civil Twilight Procyon due South at Start of Civil Twilight	September 22nd September 26th September 27th
Autumn equinox Alphard due South at Start of Civil Twilight	October 15th October 16th
Scheat due South at End of Civil Twilight Mel-111 due South at Start of Civil Twilight	November 5th November 6th
Arcturus due South at Start of Civil Twilight	December 2nd

Table 9 Possible festival days that could have been indicated by alignment of the Sun on the horizon with the megaliths when viewed from two viewpoints (x and y) positioned on the edge of the stone circles

The dates determined when each alignment occurred can be represented on a circular calendar known as the Wheel of the Year.

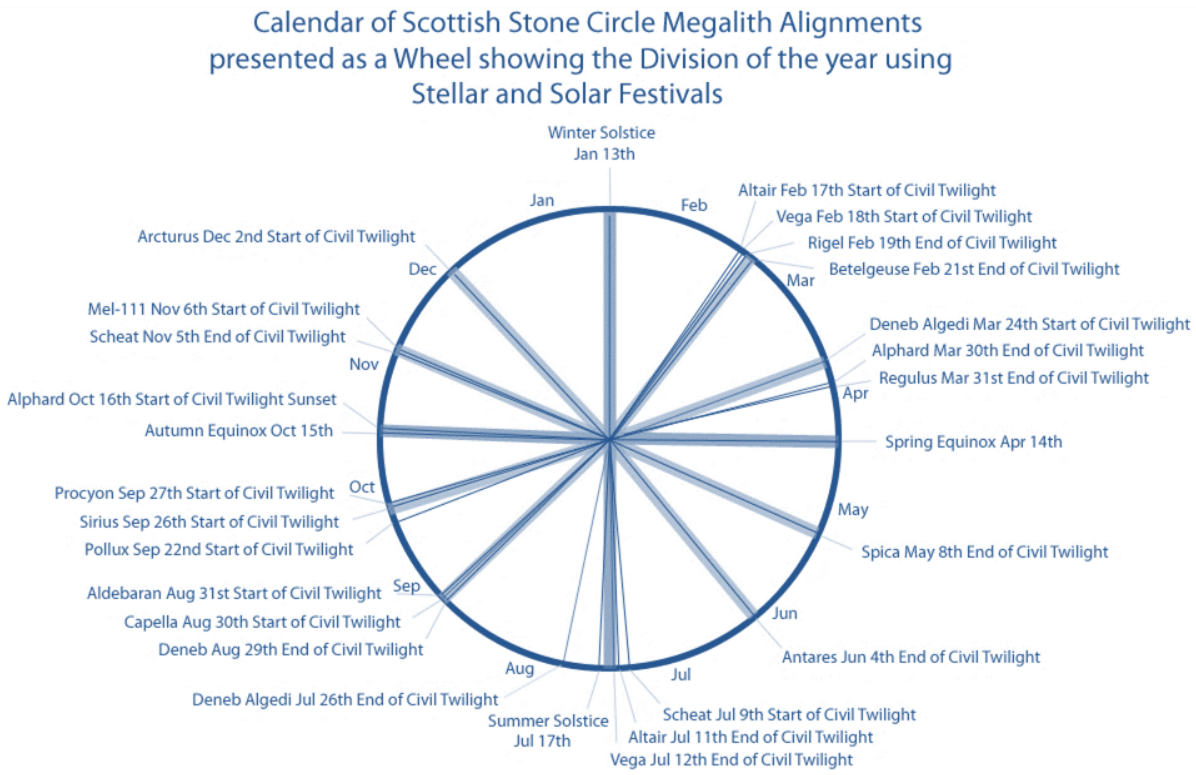


Diagram 7 The days of alignment of the Sun on the Horizon with megaliths at 3000BC from the viewing points x and y provide a remarkably symmetrical and evenly divided year of festival days. The green lines represent the solar festivals of the equinoxes and solstices and the blue lines the stellar festival days when important bright stars are aligned due South at Civil Twilight again indicated by the alignment of the megaliths with the Sun on the horizon at sunrise or sunset on those days

The winter solstice, the spring equinox, the summer solstice and the autumn equinox divide the year into four approximately equal quarters. Some of the solar festivals coincide with stellar alignments around the same time. For example, the Summer Solstice is preceded by days when Scheat and then Altair and Vega are aligned due South at Civil Twilight, whilst the day after the day of the autumn equinox, Alphard in Hydra is aligned due South, along with Regulus in Leo, at the Start of Civil Twilight. Perhaps the alignment of these stars was used as a simple marker of these solar festival days. The year is divided into eight almost equal parts by the Solstice and Equinox days combined with the days of the alignment of Betelgeuse, Antares, Deneb due South at the end of civil twilight and Arcturus due South at the start of civil twilight. These stellar festival days might have been considered as the End of Winter Festival, the Start of Summer Festival, the End of Summer Festival and the Start of Winter Festival. The period between the Spring Equinox Festival and the Start of Summer Festival is bisected by the Festival of Spica and the period between the Autumn Equinox Festival and the Start of winter Festival is bisected by the Festival of the Nine Maidens indicated by the alignment of Mel-111 at dawn and Scheat at dusk. The period between the End of Winter festival and the Spring Equinox is divided

by the festival of Deneb Algedi in Capricorn, whilst the period between the End of Summer Festival and the Autumn Equinox is divided by the Festival of Sirius and/or Procyon.

The festival days indicated by the twelve "spokes" of the wheel of the year are remarkably symmetrical and given these festivals coincide with the alignment of the brightest stars in the night sky precisely due South at Civil twilight, it seems likely that this calendar occurs by design.

Possible association between Stars and Deities

Whilst the names of the constellations we know today are different to the unknown ones that our ancient ancestors used, the identification of many as male and female figures or particular animals may have survived the passing millennia because once a constellation such as Cygnus for instance, whose stars appear to outline the shape of a long necked bird in flight, has been made, it is very difficult to undo this association so that today we call it Cygnus, the Swan but in ancient times and in different locations the constellation may have been identified with a bird more relevant to the location, such as a Goose in Scotland or a Crane in Mediterranean countries and in this way the identity of the major star patterns remains fixed for all time. The stellar festivals form pairs of festivals diametrically opposite each other across the wheel of the year calendar. For instance, the festival day of Betelgeuse in Orion the hunter is almost directly opposite the festival days of Deneb in Cygnus, Capella in Auriga and Aldebaran in Taurus. Perhaps these constellations represented animals that were vitally important to the people who built the stone circles, perhaps Cygnus was identified as the Goose, Taurus as the bull and Auriga as the deer, three animals that would have been hunted or farmed by our ancestors. The goose was particularly important as around a hundred thousand appeared from out of the blue, migrating eight hundred miles from Iceland just before the arrival of winter to provide a very important source of meat, feathers for warmth and oil for lamps, lighting the long dark winters in the Neolithic round houses.

Spica the brightest star in Virgo may have represented a goddess, perhaps the consort of Orion and her festival day lies opposite festival days where at dawn Mel-111 is aligned due South and at dusk the star Scheat is aligned due South lying directly above the Circlet of Pisces. Perhaps the nine stars visible in Mel-111 in the constellation of Coma Berenices represent the nine maidens famous in many folklore tales and the Circlet of Pisces identified in Neolithic times in Scotland as the head of the Salmon deity. Like the goose, the salmon provided a food source from “out of the blue” as salmon arrived in their tens of thousands from the Atlantic to return up the rivers to spawn in the head waters where they had begun their own lives years before. To the Picts the arrival of the salmon and goose from out of nowhere must have seemed like a heaven-sent event and their appearance in the skies in their characteristic “V” formations and the running of the salmon up estuaries and then rapids and waterfalls to spawn in the head waters

coincided with the time just after their constellations (Cygnus and Pisces) appeared due South at the End of Civil Twilight. Regulus the brightest star in Leo appears almost directly above Alphard the brightest star in Hydra, the Serpent. Five thousand years ago it is unlikely that the people of Scotland had ever seen a lion so we can speculate that perhaps the constellation was identified with another powerful and dangerous animal such as the wild boar. (The stars epsilon Leonis, lambda Leonis (Alterf) and kappa Leonis representing the upturned tusks of the celestial boar). The festival day dedicated to these two stars appears opposite a series of interesting stellar alignments on three consecutive days associated with twins, firstly with Pollux in the constellation of Gemini, the Twins and then with two dogs, Sirius, the brightest star in Canis Major, the Great Dog and then with Procyon the brightest of two stars in Canis Minor, the small dog.

The final stellar festival pairing across the wheel of the year calendar is provided by Arcturus, the brightest star in the constellation of Bootes lying opposite the festival day dedicated to Antares, the brightest star in Scorpio.

We cannot know what stories were told to incorporate these stellar deities into the ancient belief system and help to memorise the sequence of events in terms of star patterns on the different festival days during the yearly cycle. However, on one level at least there appears to be a Male Warrior, Hunter God represented by the constellation of Orion and a Female Goddess of fertility represented by Virgo which is consistent with most belief systems. Then there are animal deities represented by the constellations of Cygnus and Pisces that may have been identified with migrant populations of Greylag and Pinkfoot Geese and Salmon which appeared mysteriously from nowhere just before winter as a vital supply of food, feathers for warmth and oil for light. It would be understandable how the Salmon and Goose would be deified and venerated to ensure that these vitally important visitors would continue to return each year. Many of the other festival days involve constellations that had a significance to the lives of our ancient ancestors such as Aquila, the Eagle and Hydra, the Serpent and Taurus, the Bull and Canis Major and Canis Minor, the Dog constellations. Naturally, some of the constellations may have been identified as different animals to those associated with their constellations today such as Leo, the Lion which may have then been identified with the Wild Boar and Auriga, the Charioteer with the Red Deer (as determined from studies by the author of the Class I Pictish Symbol Stones) and Gemini the Twins may have been identified with a rectangular shield. There are some ancient stories that survive from prehistory such as the salmon of knowledge that ate nine hazelnuts that imparted great wisdom to the salmon. Perhaps this story is reflected in the festival that took place 5000 years ago at what we today would call November 5th and 6th when at the Start of Civil Twilight the group of stars known as Mel-111 in Coma Berenices was aligned due South and at the End of Civil Twilight the group of stars known as the Circlet of Pisces was aligned due

South linking a cluster of nine stars also known as the "Nine Maidens" with a Salmon on the same festival day.

How to use the Stone Circle Calendar

Sunrise Alignments

Just before sunrise, standing on the perimeter of the circle at viewpoint y and looking across the circle to the eastern horizon, as the Sun rises, if the Sun aligns with a megalith, this marks the day as a festival day.

Starting at the winter solstice alignment with the most southerly megalith on the western side of the circle in January when the Sun rises at its most southerly position, the Sun gradually moves North along the horizon until the next sunrise alignment occurs with the next megalith, now on the eastern side of the circle, on the days when Altair and Vega are due South at the Start of Civil Twilight and then Betelgeuse (the Male God) is aligned due South at the End of Civil Twilight in February. The alignment of the next megalith and the Sun at sunrise occurs at the end of March on the day that Alphard (the Adder) and Regulus (the Boar) are both aligned due South at the End of Civil Twilight. The next alignment of Megalith and Sun occurs at the Spring Equinox in April between the viewing point and the megalith that is almost due East across the circle. Then in May the Sun has moved northwards and is now aligned with the next megalith on the day when Spica in Virgo (the Goddess) is aligned due South at the End of Civil Twilight. The next megalith alignment occurs at sunrise in June on the day when Antares, the brightest star in Scorpio, is aligned due South at the End of Civil Twilight. The final most northerly megalith alignment with the Sun at sunrise occurs at the summer solstice in July but the solar festival is preceded by the stellar festivals of Pisces (the Salmon) marked by the alignment of Scheat due South at the Start of Civil Twilight followed by the days when Altair in Aquila (the Golden Eagle) and Vega in Lyra are together aligned due South at the End of Civil Twilight. The Sun at this time appears to move very little distance along the horizon and all these festivals are covered by the alignment of the Sun and the megalith as the Sun starts to now change direction moving southwards retracing its steps back along the horizon until the same stone that had marked the day of alignment of Antares now marks the days of alignment of Deneb (the Goose) at the End of Civil Twilight and Capella (the Red deer) and Aldebaran (the Bull) at the Start of Civil Twilight at the end of August. At the end of September, the Sun aligns with the megalith that had marked the day of Spica in May but now it is the alignment of Sirius associated with Canis Major and then Procyon in Canis Minor that are indicated by the alignment at sunrise with the megalith on the days when the dog stars are aligned due South at the Start of Civil Twilight. The next alignment occurs at the autumn equinox where the same megalith as the spring equinox is aligned with the Sun at sunrise on October 15th and the following day Alphard and Regulus are aligned together due South at the Start of Civil Twilight. The next alignment occurs at the

beginning of November when the Sun aligns with the megalith standing below the equinox megalith when Scheat is due South at the End of Civil Twilight and the next morning at the Start of Civil Twilight, Mel-111 is aligned due South. At the beginning of December the megalith that indicated the alignment of Betelgeuse now heralds the day of alignment of Arcturus in Bootes at the Start of Civil Twilight. Finally the most southerly positioned stone is aligned with the rising Sun on the day of the Winter solstice completing the annual cycle of alignments from our perspective on Earth, the Sun slowly changes direction once more and the cycles of alignment are repeated as once again the Sun appears to move North along the horizon.

Sunset Alignments

Standing at the viewpoint (x) on the eastern perimeter of the circle, alignments between the Sun on the horizon at sunset and the megaliths to the West of the viewing position indicate special festival days in the Neolithic calendar. The festival days marked by the sunset alignments are by in large the same festival days indicated by the sunrise alignments (see Diagram 6).

At the winter solstice on January 13th the Sun on the horizon at sunset aligns with the southernmost stone of the eastern side of the circle. The Sun moving northwards along the horizon aligns with the next stone in February where the sunset alignment marks the day of alignment of both Altair in Aquila and Vega in Lyra due South at the start of civil twilight on February 17th and 18th and then when the next megalith aligns with the setting Sun, Rigel aligns due South at the end of civil twilight on the !9th and finally on the 21st February Betelgeuse in Orion is aligned due South at the end of civil twilight. The next alignment of the setting Sun with a megalith occurs at the spring equinox on April 14th. The alignment of the setting Sun with the next megalith occurs on May 8th when Spica in Virgo is due South at the end of civil twilight. Then on June 4th the most northerly stone on the western side of the circle is aligned with the setting Sun on the day when Antares in Scorpio is aligned due South at the end of civil twilight. Between July 9th and July 26th, the final megalith aligns with the setting Sun as it reaches its most northern point in its oscillating motion along the horizon. Scheat is aligned due South at the start of civil twilight on July 9th whilst the summer solstice is marked by the alignment of the setting Sun on July 17th and finally as the Sun starts to move South again still aligned with the same megalith on July 26th the star Deneb Algedi in Capricorn is aligned due South at the end of civil twilight.

The Sun at sunset is now moving southwards along the horizon and it once again aligns with the most northerly stone of the circle on August 29th when Deneb in Cygnus is aligned due South at the end of civil twilight. In the morning, Capella, the brightest star in Auriga is aligned due South at the start of civil twilight and the day after on August 31st Aldebaran in Taurus is aligned due South at the start of civil twilight. The next stone South

on the western side aligns with the setting Sun on September 22nd when Pollux in Gemini is aligned due South at the start of civil twilight. The next stone to become aligned with the setting Sun is the megalith located due West of the viewing position (y) on the day of the autumn equinox. The following day marks the alignment of Aldebaran and Regulus in Leo which appear due South at the start of civil twilight. On November 5th the alignment of the next stone at sunset marks the day of alignment of Scheat and the Circlet of Pisces due South at the end of civil twilight followed the next morning by the alignment of Mel-111 in Coma Berenices due South at the start of civil twilight.

The most southerly stone on the western side of the circle is aligned with the setting Sun on December 3rd when Arcturus in Bootes is aligned due South at the start of civil twilight. Finally, the year comes full circle with the alignment of the setting Sun with the final megalith on the day of the winter solstice on January 13th. The Sun once again starts to turn North to repeat the cycle of festivals.

There is a missing stellar alignment relating to stone h which has only one alignment around 5th November and requires another alignment as the Sun is moving North along the horizon before the spring equinox. The missing alignment can be calculated to occur on the 24th March and when the night sky is observed for that date there is an alignment on that day at the start of civil twilight with the brightest star in Capricorn, Deneb Algedi. The author proposes that the great significance of Capricorn in these ancient pre-Christian times has been forgotten. The belief at this time in Scotland was that the stars in Capricorn represented the Great God and that its pattern of stars formed a Cat-head deity. The reason for the great importance of Capricorn at this time was its perceived role as protector god of the Sun during the winter months as the constellation rose and set with the Sun and was therefore not visible in the night sky during the winter months. This stellar deity was therefore considered to be the protector of the Sun during the dark winter months and was considered as the Great God due to the overriding importance of this role and the return of lighter, longer, warmer days at the end of winter marked by the reappearance of the stars of Capricorn in the night sky.

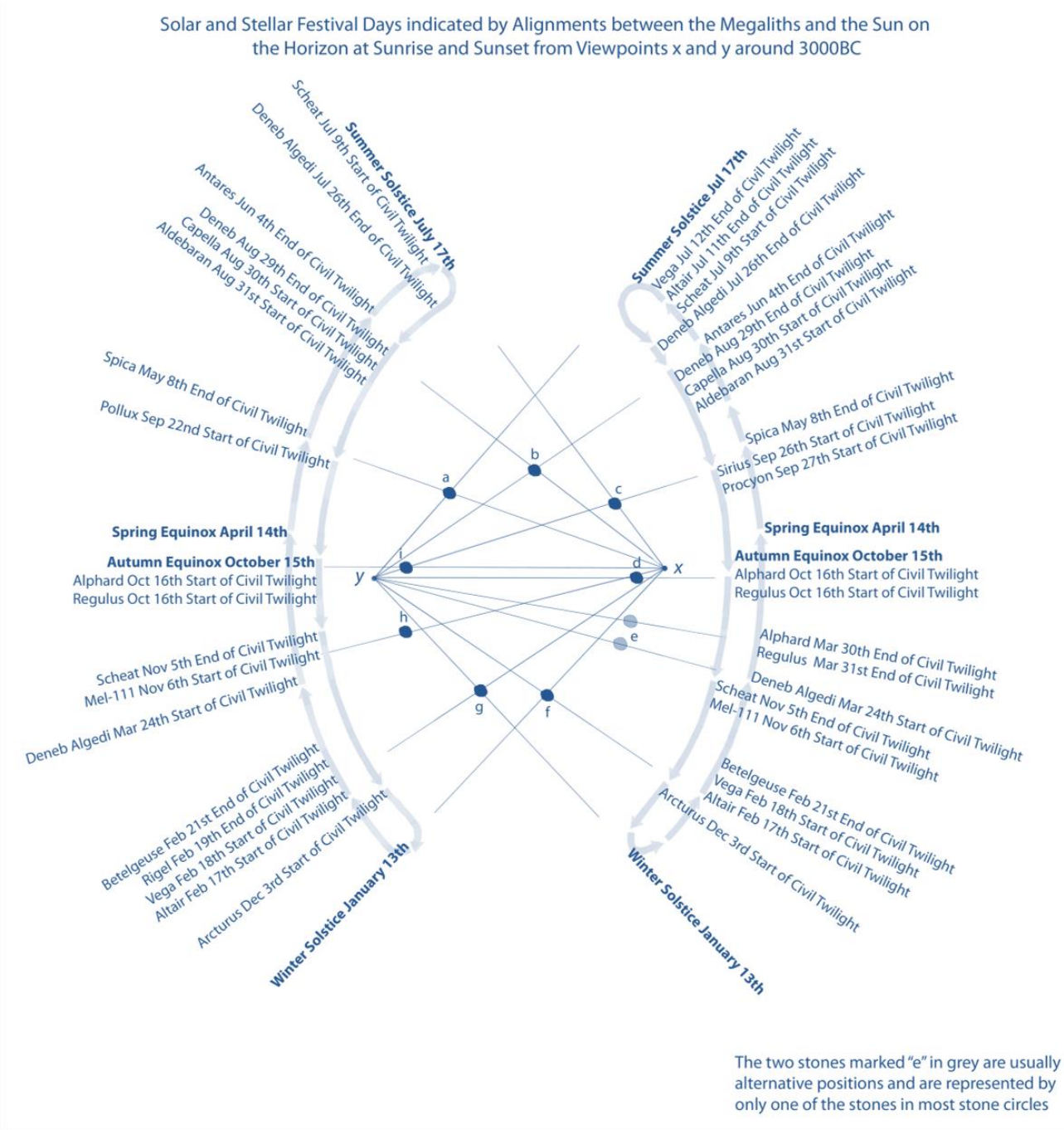


Diagram 6

Shows how alignments between the Sun on the horizon and megaliths located around a circle mark the days when the brightest stars appear due South at the Start of Civil Twilight at dawn or the End of Civil Twilight at dusk when the alignments are made from two peripheral viewpoints x for sunset alignments and y for sunrise alignments.

The alignment of megaliths with the Sun suggests that the date of building and using the stone circles was during a period lasting up to 200 years. The stone alignments give the best fit for 3000bc plus or minus 100 years indicating that after around 2800bc the positions of the megaliths no longer gave the same precise alignments they had done when they had been first erected for the days when the brightest stars appeared due South in the night sky at dawn or dusk. Apart from the alignment of the Sun on the days of the equinoxes and solstices, the stone circles became redundant as calendrical tools as the stones would need to have been repositioned. The problem with moving the stones to counteract the effects of precession and the movement of the stars is that each megalith was used as a marker for at least two stellar festival days and in most cases the direction of adjustment of the stone position required to maintain the alignment with the Sun on the horizon was in conflict for the different stars indicated by alignments of the Sun with the same stone (See Appendix III). However, the fact that the stone circles were unable to be altered to take account of precession means that their original date of construction is more easily determined. The question raised by the suggestion that after 2800BC the stone circles were no longer useful as calendrical devices is did the calendar or beliefs in the stellar deities change or was another calendrical tool developed such as represented by the later numerous penannular brooches and Nebra Disc which may have provided more convenient portable calendrical tools that in the former example were mis-identified as simple brooches.

Conclusions

The stone circles of Scotland could have been used by Neolithic man as calendrical devices to identify festival days some five thousand years ago. By standing at two different viewing positions; one on the western perimeter and the other on the eastern perimeter of the circle and aligning the Sun on the horizon at sunrise and sunset with megaliths, special festival days could be identified as both the four solar festivals comprising the days of the summer and winter solstices and the autumn and spring equinoxes and stellar festival days when important bright stars were aligned due South at Civil Twilight. Around 3000 BC in Scotland, the stars and their associated constellations may have been identified as star gods and deities and this association may give us an insight into the beliefs of our ancient ancestors. We can speculate using the star and constellation names we know today that Betelgeuse in Orion may have represented a male god and Spica in Virgo a Goddess. The star Deneb in Cygnus may have been identified as an avian, possibly Goose deity and the bright star Scheat directly above the group of stars known as the Circlet of Pisces a fish, possibly marked a festival day dedicated to a Salmon deity. The other stars such as Capella in Auriga and Alphard in Hydra may have been associated with other animal deities such as the red deer and adder whilst the star cluster known as

Mel-111 in the constellation of Coma Berenices may have been associated with the Nine Maidens described in popular mythology. Other stars may have represented other deities in a pantheon of prehistoric star gods that had a relevance to the lives of the people who built these stone circle monuments. The importance of a male warrior god and female goddess of fertility figure is readily understood as it is common to most belief systems throughout the world and likewise the local importance of migratory geese and salmon which appeared in their tens of thousands in Scottish skies and rivers from out of the blue before winter as a "heaven sent" source of food could explain the importance of and the identification of the constellations of Cygnus and Pisces with the goose and salmon to the people who built these megalithic structures. The solar and stellar festival days divided the year into a remarkably even and symmetrical distribution of time periods that have the appearance of a planned calendar that would allow farming and hunting activities to be organised throughout the year and also to provide a series of communal festivals dedicated to the celebration and veneration of the stellar deities to help protect and provide for a healthy, well-fed people. In decoding the stone circles both the beliefs and calendar of our ancient ancestors living around 3000BC may finally have been revealed.

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Appendix I

Determination of the Viewing Positions and analysis of the significance of alignments

The stone circles judged to be most complete in terms of an even distribution of megaliths around the circle containing a good number of stones (minimum of three on each side of the circle) positioned around the circumference were selected to test the significance of the peripheral viewpoint proposition. The eight stone circles selected were Aquorthies Manar, Loch Mannoch, Tyrebagger, Sunhoney, Cullerlie, Blindwells, Colen and Leys of Marlee. The hypothesis that two peripheral viewing positions were used to determine the days when megaliths aligned with the rising and setting Sun was tested on a sample of stone circles. The objective was to find a viewing point just outside the eastern perimeter that aligns with three megaliths and the Sun on the horizon at sunset on the days of the spring and autumn equinoxes and the summer and winter solstices and similarly a second viewing point on the western perimeter that aligns with three megaliths at sunrise on the same days. The choice of stone circles could be argued to be subjective but the purpose of this preliminary study was only to establish whether a general principle for locating the viewing positions, could be established and to then apply this principle to all 36 stone circles in order to establish the bearings of all the megaliths relative to those viewing positions. Some rules for alignment were made to allow the probability that the alignments between the Sun and the megaliths when viewed from the two viewing points occurred by design rather than by chance. The first objective is to identify the two viewing points one for sunrises on the western side of the circle and the other for sunsets viewed from a position on the eastern side of the stone circle. Two alignments are required to identify each of the viewing points. The first alignments chosen were those of the Sun on the horizon on the days of the equinoxes at sunrise and sunset. The alignments of the Sun at sunrise and sunset on the days of the spring and autumn equinoxes are approximately due East and due West respectively, the precise bearings for 3000BC are 89.28˚ and 88.18˚ for sunrise on the spring equinox and autumn equinox respectively and 270.97˚ and 271.6˚ for the sunset on the same equinox days. The first rule was that the equinoctial megaliths were selected as the two megaliths, one on the eastern side and the other on the western side, lying closest to the East-West axis passing through the circle's centre. Lines representing the mean bearings for the equinoxes were drawn through the two equinoctial megaliths. The viewing points, if they existed, should lie at some point on these lines on or outside the perimeter of the stone circle. In order to establish the precise viewing points a second bearing is required and the alignment of the Sun on the horizon with megaliths on the day of the summer solstice was chosen. The point at which the equinox alignment and the summer solstice alignment intersect identifies each of the proposed viewing positions. The second rule was that the megaliths indicating the day of the summer solstice were chosen as being the second most northerly megalith located on either side of the circle (in this case though, unlike the

equinoctial megaliths, the megaliths are positioned on the same side of the circle as the viewing point). A line bisecting the second most northerly stone on the same side of the circle as the viewing point was drawn that coincided with the bearing of the Sun on the horizon at sunrise and sunset on the day of the summer solstice. The bearings of the Sun on the horizon on the day of the summer solstice for 3000BC were 39.43˚ for sunrise and 320.61˚ at sunset. The point at which the summer solstice alignment and equinox alignments intersect on the eastern side of the circle identifies the viewing point for the sunset alignments and the position where the two lines intersect on the western side of the circle identifies the viewing point for the sunrise alignments.

Having identified the viewing points for the sunrise and sunset alignments for the days of the equinoxes and the summer solstice, a line representing the bearing of the Sun on the day of the winter solstice can be drawn from the viewing points indicated by the equinox and summer solstice alignments to see whether this alignment coincides with a third megalith located in the south-south west and south-south east sectors of the stone circles. If the megaliths were positioned by design to indicate the days of the equinoxes and solstices then it would be expected that all three megaliths would align with the Sun at sunrise when viewed from the western viewpoint and another three megaliths would align with the Sun at sunset when viewed from the eastern viewpoint.

In order to estimate the probability of a megalith aligning with the winter solstice Sun at sunrise and sunset the sectors where the stones would need to be located for an alignment to occur were examined. The sectors of interest are the south-west to South arc representing a bearing range measured from the centre of the circle of 135˚ to 180˚ and the South to south-east arc representing a bearing range of 180˚ to 225˚. The angle covering these two ranges can be measured from the established viewing points. Then it can be determined whether a megalith is located in each of these sectors. If a megalith is located in the sector and at least part of the stone is aligned with the Sun on the horizon on the winter solstice, then the probability of this occurring by chance can be calculated by considering first the number of stones in the circle and the probability that any one of these stone will be located in the relevant sectors (135-180˚ and 180-225˚) if the distribution of megaliths was random and then calculate the probability that the stone itself would align with the winter solstice Sun at sunrise and sunset from the two viewpoints by considering the angle of arc covered by the megalith itself as a proportion of the angle of the sectors when viewed from the viewpoint. The probability of a stone occurring in each sector is multiplied by the probability that it will coincide with the winter solstice alignment. The probability that both sunrise and sunset alignments of the winter solstice will coincide with two megaliths can be obtained by multiplication and likewise the probability that all eight stone circles will exhibit alignments for all three solar festivals calculated by multiplication of the individual probabilities. It is interesting that of the 8 stone circles all 16 of the winter solstice alignments coincide with a megalith. The precise

alignment of the Sun on the horizon at the winter solstice might be expected to bisect the megalith and this is the case with 8 of the 16 stones. A degree of leeway is considered by firstly measuring the probability of the alignment occurring within the breadth of the stone, where the breadth is measured as an angle from the viewpoint. This will on one hand maximise the probability of the stone being considered to be aligned but on the other hand will maximise the probability that the alignment occurs by coincidence thereby giving a more conservative value for the probability.

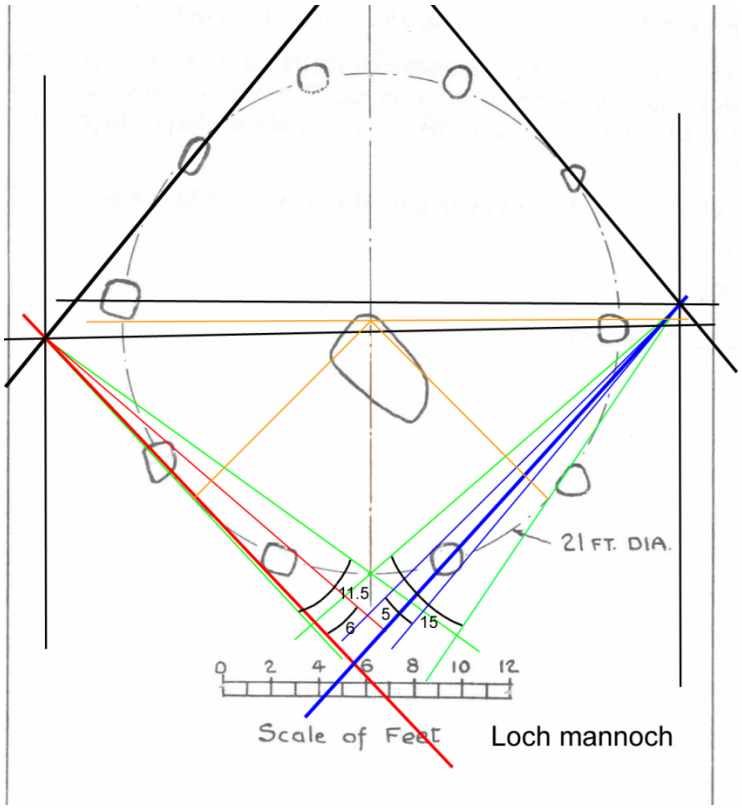
The method of establishing the location of viewpoints is to use the alignments between the megaliths and the Sun on the horizon on the days of the summer solstice, the autumn and spring equinoxes and the winter solstice. The first step is to identify the megaliths that were used to make the alignment between the Sun on the horizon for the equinoxes which occur on the days when the Sun is around 89.5 degrees at sunrise and 270.5 degrees at sunset. The megaliths used for alignment at the equinox are proposed as the megaliths closest to the East-West line thgat passes through the centre of the circle. One megalith on the eastern perimeter is identified as the megalith that aligns with the Sun at sunset on the days of the equinoxes when viewed from a viewpoint on the western perimeter and a second megalith on the western perimeter is identified as the megalith that aligns with the Sun on the horizon at sunrise on the days of the equinoxes when viewed from a viewpoint on the western perimeter.

The second step is to identify the megaliths that align with the Sun on the horizon at sunrise and sunset on the day of the summer solstice. The megaliths proposed are the second most northerly megalith on either side of the North-South axis. The bearing of the Sun at sunrise is around 39.5 degrees and 320.5 degrees at sunset at the summer solstice. Lines are drawn to bisect the summer solstice megaliths and the points that they intersect with the equinox lines identify the two viewpoints.

Probability that alignments occur between megaliths and the Sun on the days of the solstices and equinoxes from the two viewpoints "X" and "Y".

The viewpoints x and y can only be determined by using the alignments of the Sun on the horizon for two of the solar festivals, in this case the autumn and spring equinoxes are considered as one alignment as the bearing of the Sun on the horizon is virtually the same for both equinoxes. The probability of the third solar festival being identified by alignment from the determined viewpoint can be estimated by considering the probability of a megalith being located in the appropriate sector given the number of stones in the circle and that the stone is aligned within its width.

Lines corresponding to bearings of around 136.5 degrees (thick red line) for sunrise and 223.5 degrees (thick blue line) for sunset were drawn from the proposed viewpoints to determine whether these lines coincided with megaliths in the South-South-East and South-South-West sectors of the circle.



In order to measure the probability of a megalith aligning with the Sun at the winter solstice at sunrise or sunset the arc angle corresponding to 135-180 degrees and 180-225 degrees was measured from the relevant viewpoint x or viewpoint y (green lines). The arc angle corresponding to the width of any stone present in that sector measured from the viewpoint aligning with the winter solstice alignment was measured (thin red and blue

lines) and the probability of alignment determined by dividing the arc angle of any aligned stone by the angle of the 45 degree arc as measured from the same viewpoint.

The probability of two viewpoints (x and y) aligning with megaliths and the rising and setting Sun on the days of the solstices and equinoxes can be estimated.

The problems with trying to make some statistical analysis with a group of ancient stone circles is firstly the condition of stone circles where megaliths have been toppled, moved or have missing stones and are now incomplete. Eight stone circles surveyed by Thom were chosen as relatively complete stone circles for further examination.

Aquorthies Manar

Tyrebagger

Sunhoney

Blindwells

Colen,

Leys of Marlee

Loch Mannoch

Cullerlie

The second issue is how the location of the hypothetical viewing points for each stone circle can firstly be identified in a consistent manner and then examined to make an assessment of the probability that any solar alignment occurred by chance.

The method chosen for the identification of the sunrise and sunset alignment positions was to identify a megalith on the eastern periphery of the circle that would align with the Sun on the horizon at sunrise on the days of the equinoxes. A megalith on the western periphery of the circle that could be used to align with the setting Sun on the days of the equinoxes was then identified. In each case the megaliths chosen were those that were located closest to the line of the East-West axis passing through the circle.

Having drawn a bearing line of approximately 89 degrees through the eastern sunrise equinoctial megalith and a bearing line of approximately 271 degrees through the western sunset equinoctial megalith, a second bearing line was drawn through megaliths aligned with the rising and setting Sun at the summer solstice. The stones chosen for alignment at sunrise and sunset at the summer solstice were the second most northerly stones erected in either hemisphere of the stone circle. The bearing of the lines drawn through the approximate middle of these megaliths were 39.4 degrees and 320.6 degrees

representing the alignment of the Sun on the horizon at sunrise and sunset respectively on the day of the summer solstice.

When the bearing lines for the summer solstice and the equinoxes are extrapolated, they intersect with each other at two points one East of the stone circle and the other West of the stone circle, these represent our viewing positions (x and y).

Having established two viewpoints that allow the days of the equinoxes and summer solstice to be identified by alignment of the Sun on the horizon with four megaliths, two for sunrise alignments and two for sunset alignments, the idea of peripheral viewpoints can be tested by determining whether two further megaliths from these viewing points coincide with the alignment of the Sun on the horizon at sunrise and sunset on the day of the winter solstice.

The bearing of the Sun at the winter solstice is 136.7 degrees at sunrise and 223.2 degrees at sunset. Drawing these lines from the points x and y should go through two megaliths situated on the south east and south-west perimeter of the stone circles to support the idea that the stone circle could have been used as a solar calendar.

A preliminary examination shows that the winter solstice bearing of the Sun at sunrise and sunset consistently coincides with the position of a megalith from the peripheral viewing positions "x" and "y". In order to estimate the likelihood of this occurring by chance there are two parameters that can be measured; 1) the chance that a megalith would be present in the required sector for alignment and 2) what percentage of the sector represented by South to south-east and South to south-west angle when viewed from x and y is accounted for by the angle sector determined by the dimension and position of the megalith when viewed from the same x or y viewpoint.

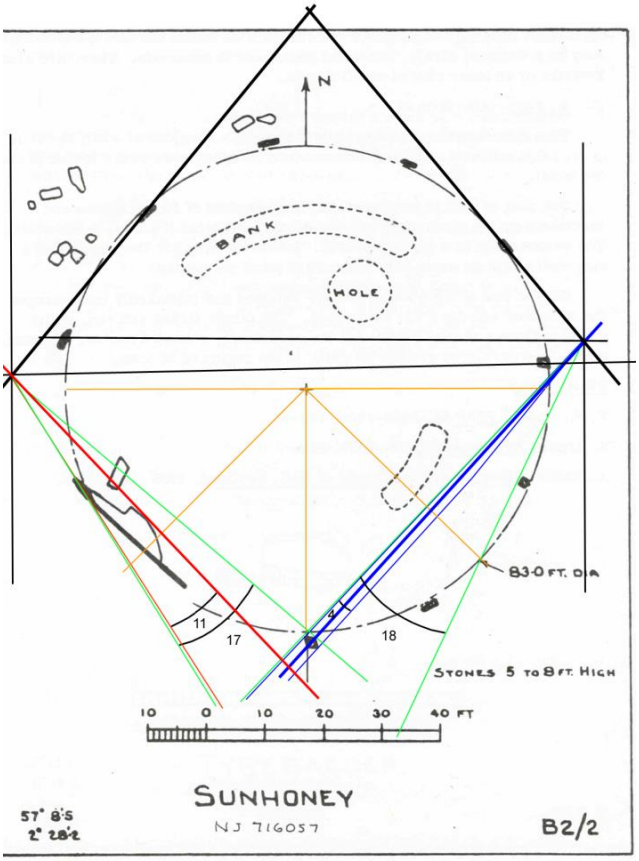
As an example, if there are 6 stones in the eastern hemisphere of the stone circle and 5 stones on the western hemisphere of the stone circle then the chances, if the megaliths were randomly positioned, that there is a stone located in the S-SW sector (180- 225 degrees) for sunset alignments is 5:4 and 6:4 for sunrise alignments in the SE-S sector (135-180 degrees). The angle of arc covered by the megalith's width from the viewpoint can be measured at say 6 degrees and the angle of arc of the S-SE sector itself measured from y for sunrise alignments may be say 18 degrees in which case the chance that a stone is located in the correct sector and that it is aligned within the width of the stone, with the Sun at the winter solstice at sunrise from position y is (6/4) x (6/18) or 36/72 or 1/2, the same procedure can be carried out for the megalith aligned with the setting Sun at the winter solstice. This analysis takes no account of the probability that the equinox and summer solstice alignments also coincide with megaliths because they were used to identify the unknown viewpoint positions "x" and "y". The probability in this example also takes no account of how close to the centre of the of the stone the alignment is.

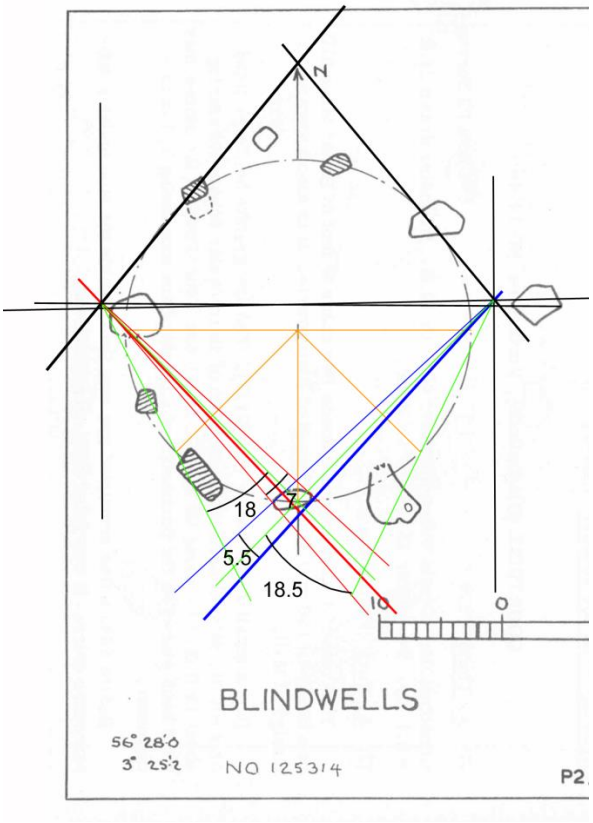
The probabilities that both sunrise and sunset alignments were indicated for the winter solstice can be calculated by multiplication of the individual probabilities. Likewise, the probability that all eight of the selected stone circles exhibit winter solstice alignments can be calculated by multiplication.

Stone Circle	Probability of Stone being located in sectors 135-180˚ and 180-225˚	Probability of Stone Aligning with Sun at Winter Solstice sunrise	Probability of Stone Aligning with Sun at Winter Solstice sunset	Probability of Stone being located in correct sector and aligned with the Sun at the Winter Solstice at sunrise	Probability of Stone being located in correct sector and aligned with the Sun at the Winter Solstice at sunset	Probability of Stone circle having two megaliths in the correct sectors and aligned with the Sun at the winter solstice at sunrise and sunset (Stone width)	Probability of Stone circle having two megaliths in the correct sectors and aligned with the Sun at the winter solstice at sunrise and sunset (Stone middle)
Aquorthies Manar	6:4 6:4	6:29	1:6	9:29	1:4	9:116 0.0754	0.0754
Loch Mannoch	5:4 5:4	12:23	1:3 (2:15)	15:23	5:12 (1:6)	25:92 0.272	5:46 (0.109)
Tyrebagger	6:4 6:4	12:33 (4:33)	12:29	6:11 (2:11)	18:29	108:319 0.3386	36:319 (0.113)
Sunhoney	6:4 6:4	11:17	2:9 (1:9)	33:34	1:3 (1:6)	11:34 0.324	11:68 (0.162)
Cullerlie	4:4 4:4	13:23 (4:23)	32:33 (4:33)	13:23 (4:23)	32:33 (4:33)	416:759 0.548	16:759 (0.021)
Leys of Marlee	3:4 3:4	32:25 (4:25)	7:36	99:100 (12:100)	7:48	231:1600 0.1444	7:400 (0.0175)
Blindwells	5:4 6:4	7:18 (1:9)	11:37	35:72 (5:36)	33:74	385:1776 0.217	55:888 (0.0619)
Colen	6:4 5:4	21:30	18:41	21:20	45:82	189:328 0.576	189:328 0.576

The approximate probability of a megalith being located in the relevant sector of the circle for alignment with the Sun on the horizon on the day of the winter solstice is calculated by counting the number of megaliths on each side of the North-South axis of the stone circle and dividing that number by the four 45 degree sectors in that half circle (in some instances stones straddle the N-S axis but these are rarely useful for solstice alignments because they are either too northerly for summer solstice alignment or too southerly for winter solstice alignment). The probability of a megalith aligning with the Sun on the horizon on the day of the winter solstice can be calculated by measuring the angle of arc covered by the megalith from the viewpoint and dividing that angle by the angle of arc covered by the S-SW or SE-S sector as measured from the viewpoints. The probability that a pair of megaliths are located in the appropriate sectors and are aligned with the Sun at sunrise and sunset can be calculated by multiplying the individual probabilities. The probability that all eight selected stone circles exhibit alignments with six megaliths with the Sun on the horizon on the days of the summer solstice, the autumn and spring

equinoxes and the winter solstice from the x and y viewpoints can be estimated by multiplying the probability for each stone circle. The figure obtained is approximately 1:45000 which strongly supports the hypothesis that two viewpoints could have been used to identify the days of the solar festivals by alignment of the megaliths and the Sun on the horizon at both sunrise and sunset. The criticism that the group of stone circles was selected is countered in part by the conditions for selection, such as the number of stones present and the completeness and condition of the stone circles. It should also be considered that the selected stone circle sample comprises 22% of the total number of circles considered in the study. Furthermore, the probability of alignment of the megaliths with the Sun on the horizon has considered the whole width of the megalith whereas in practise 8 of the 16 megaliths are almost bisected by the line of alignment that would reduce the probability of alignment considerably. Most significantly the analysis of eight stone circles is a preliminary study to establish rules for the analysis of all 36 stone circles establishing the idea of two viewing points and the position of the megaliths used for alignment of the Sun on the days of the equinoxes and solstices.

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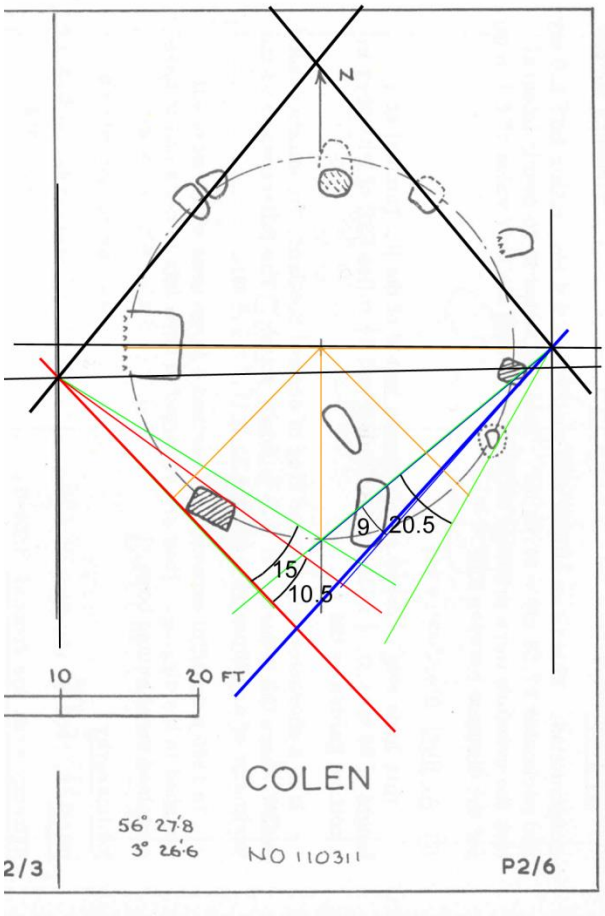
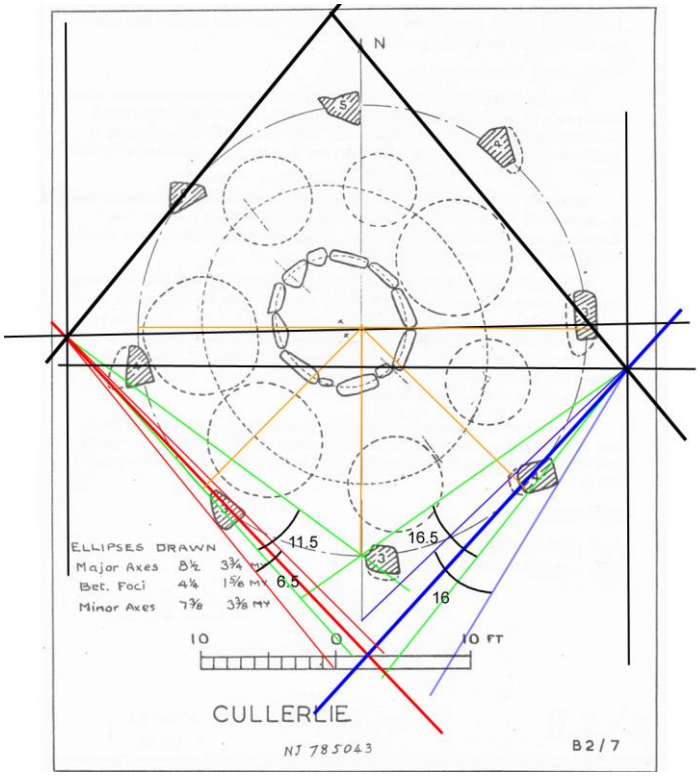
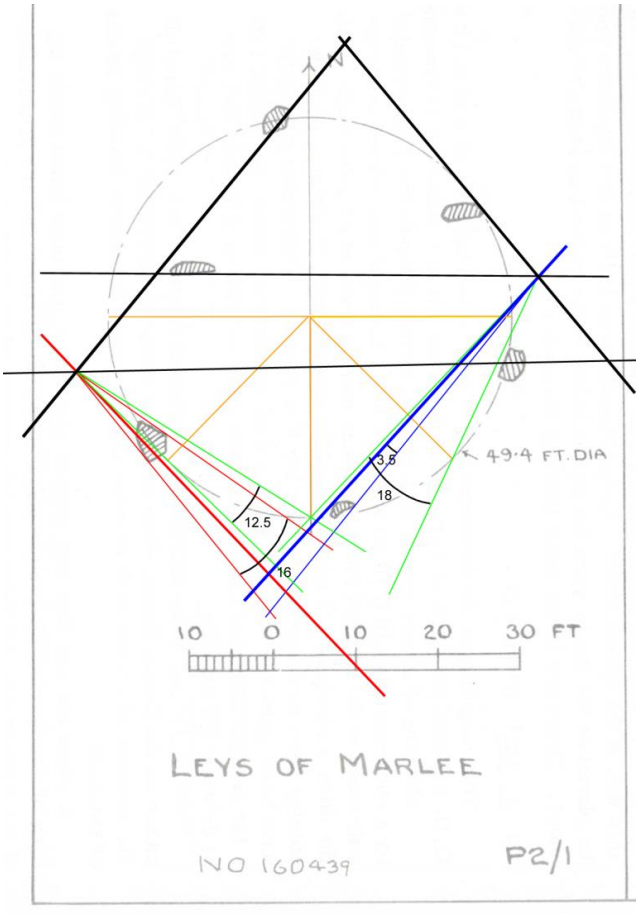
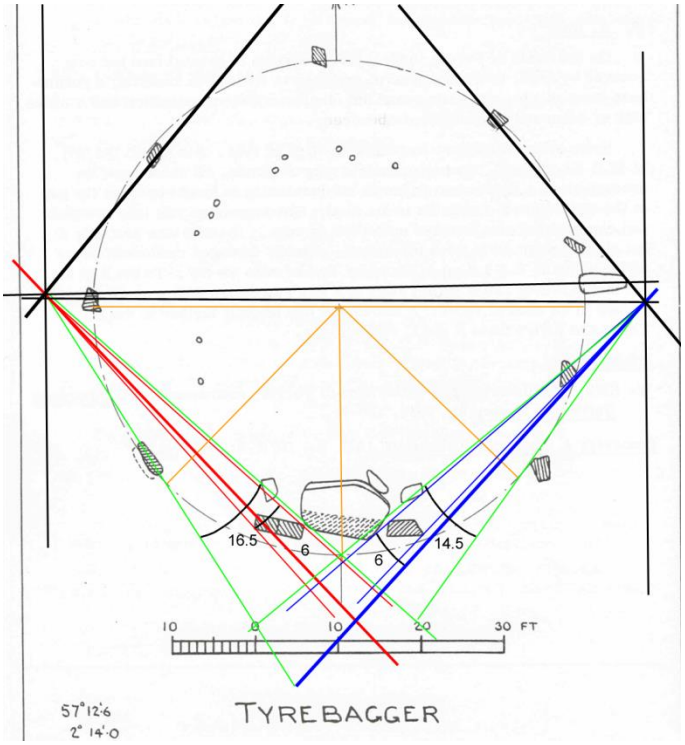
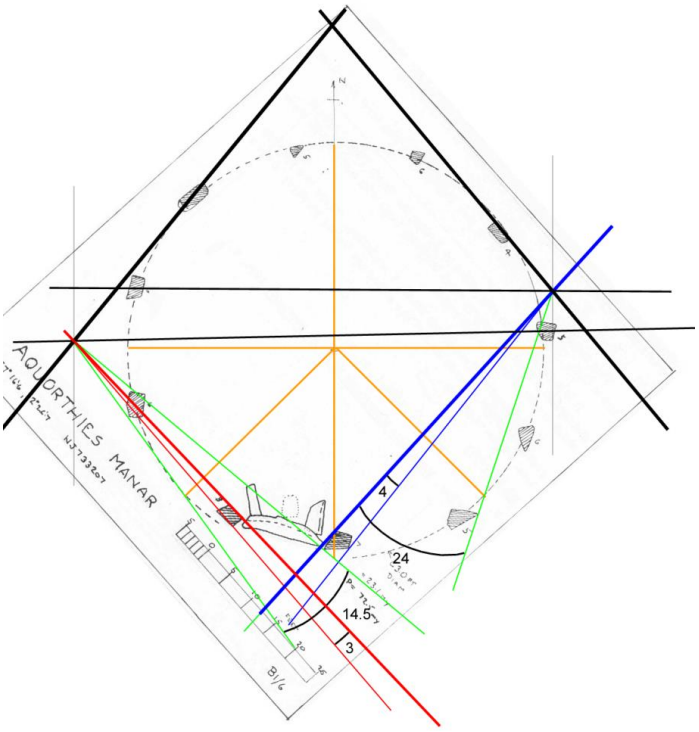
18
5.5
18.5
10
0
BLINDWELLS
56° 28·0
3° 25·2
NO 125314
P2


N
9
20.5
15
10.5
10
20 FT
COLEN
56° 27·8
3° 26·6
NO 110311
2/3
P2/6


N
ELLIPSES DRAWN
Major Axes 8½ 3¾ MY
Bet. Foci 4¼ 1⅝ MY
Minor Axes 7⅜ 3⅜ MY
11.5
6.5
16.5
16
10 0 10 FT
CULLERLIE
NJ 785043
B2/7

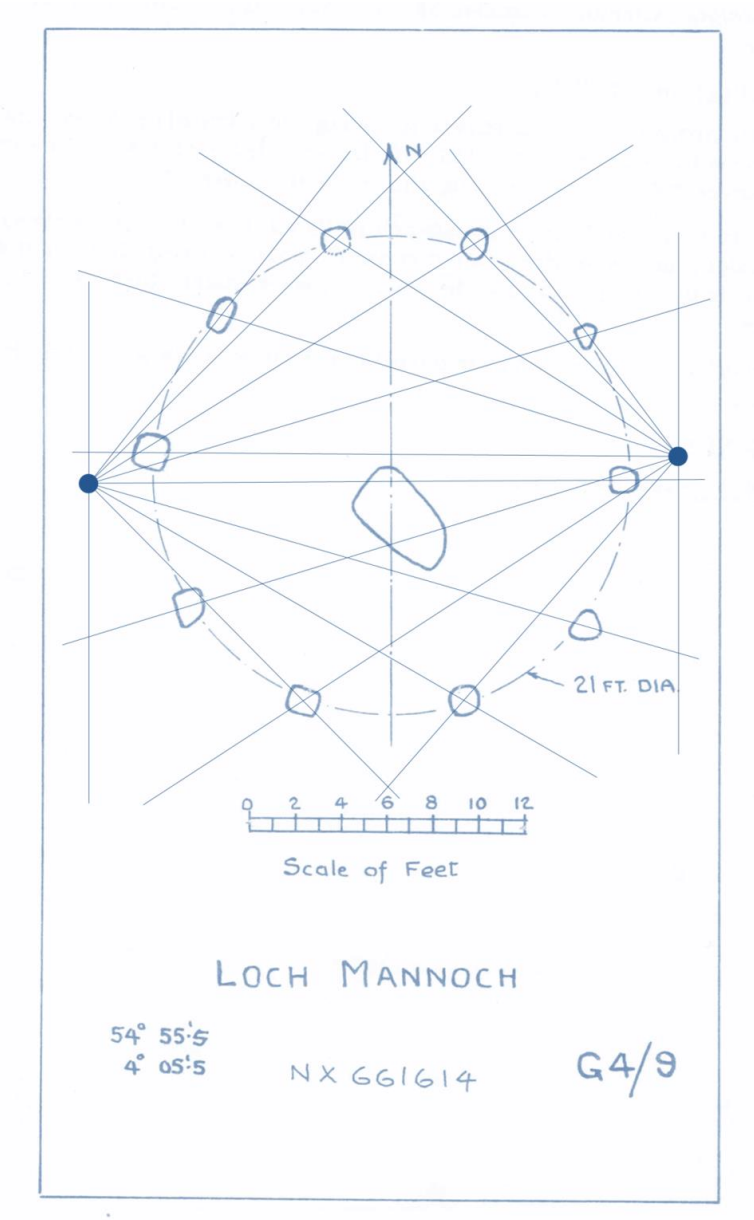

N
49·4 FT. DIA
3.5
18
12.5
16
10 0 10 20 30 FT
LEYS OF MARLEE
NO 160439
P2/1

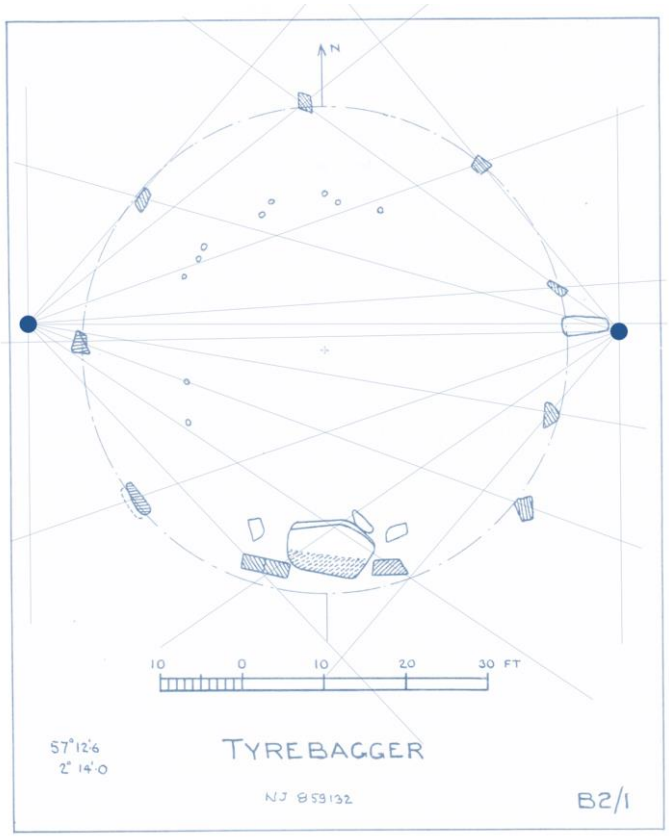

16.5
6
6
14.5
10
0
10
20
30 FT
57°12·6
2° 14·0
TYREBAGGER

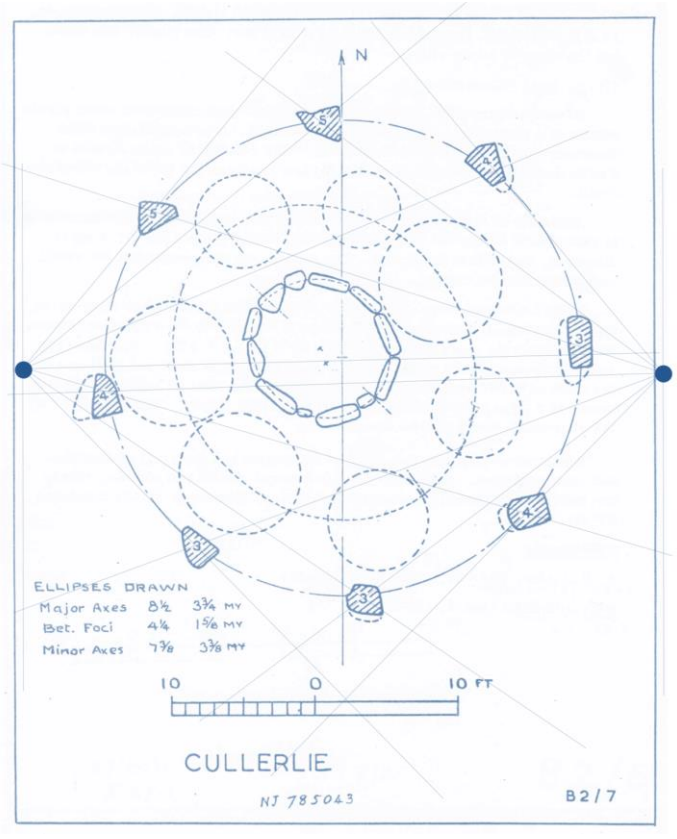

AQUORTHIES MANAR
4
24
14.5
3

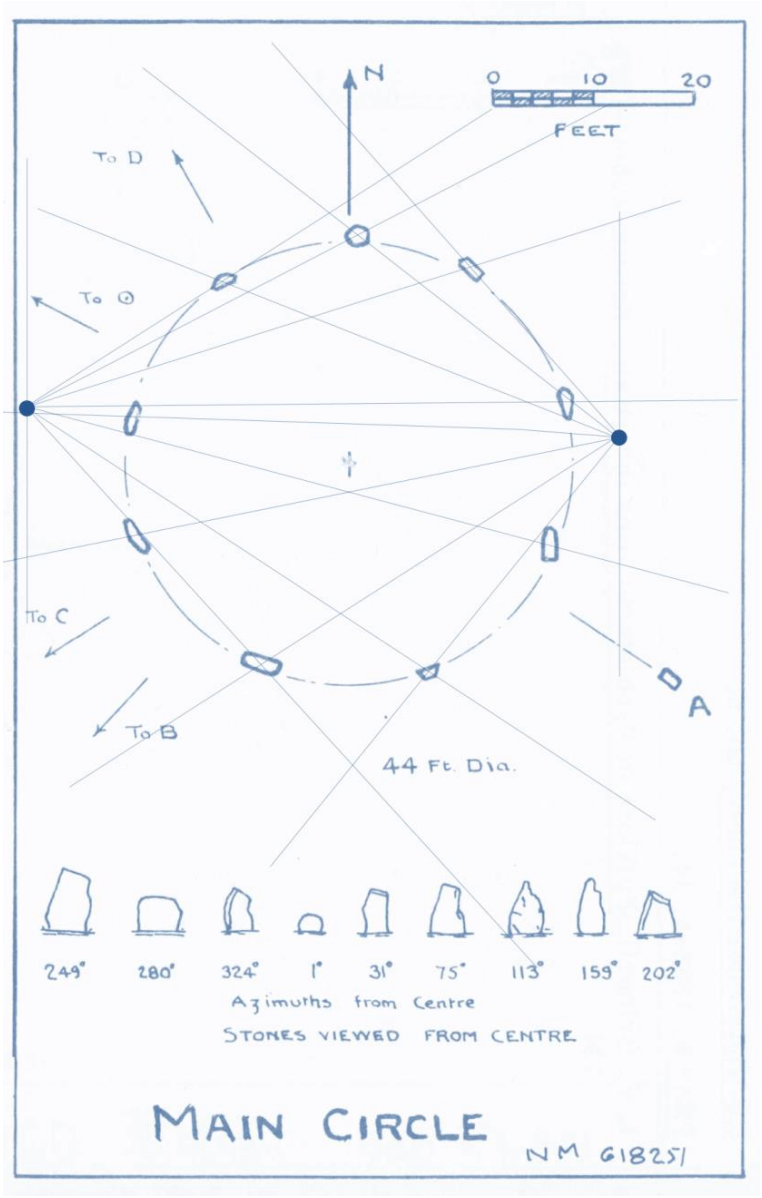
Appendix II

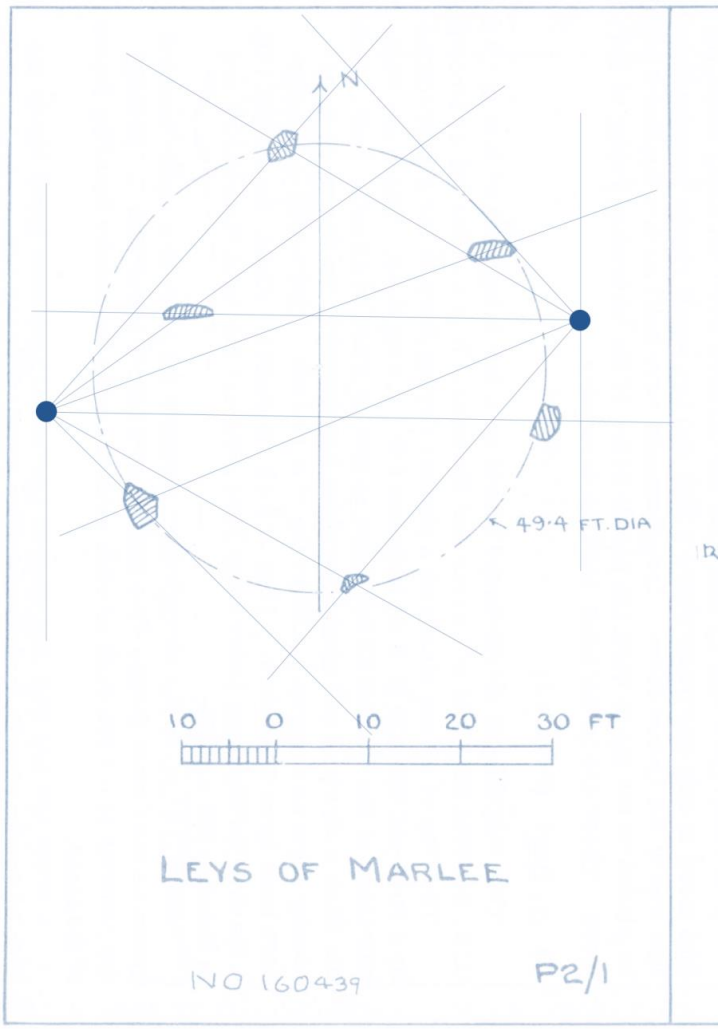
Viewpoints and alignment with Megaliths determined for 36 stone circles using the alignments of the Sun on the horizon at sunrise and sunset with megaliths on the days of the solstices and equinoxes to establish the location of the viewpoints. Plans are those taken from A. and A.S. Thom, Megalithic Rings collated by A. Burl, British Archaeological Report 81, 1980 and overlain with sunrise and sunset viewpoints and lines from viewpoints through the megaliths.

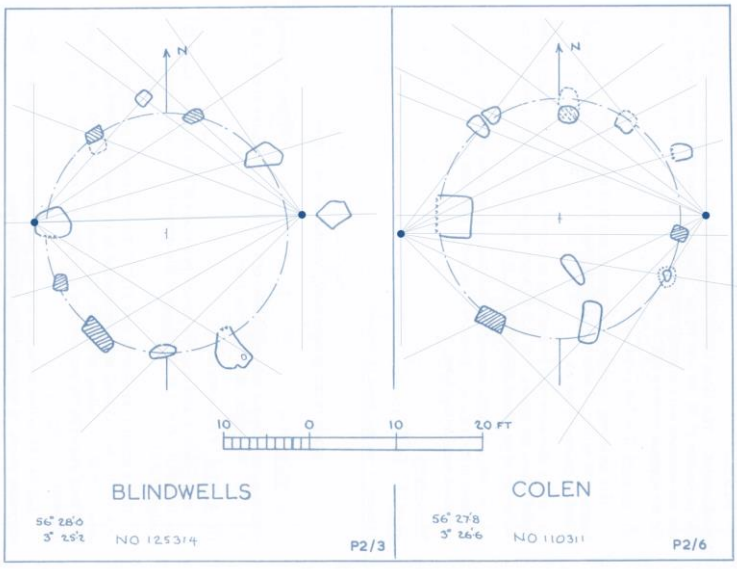


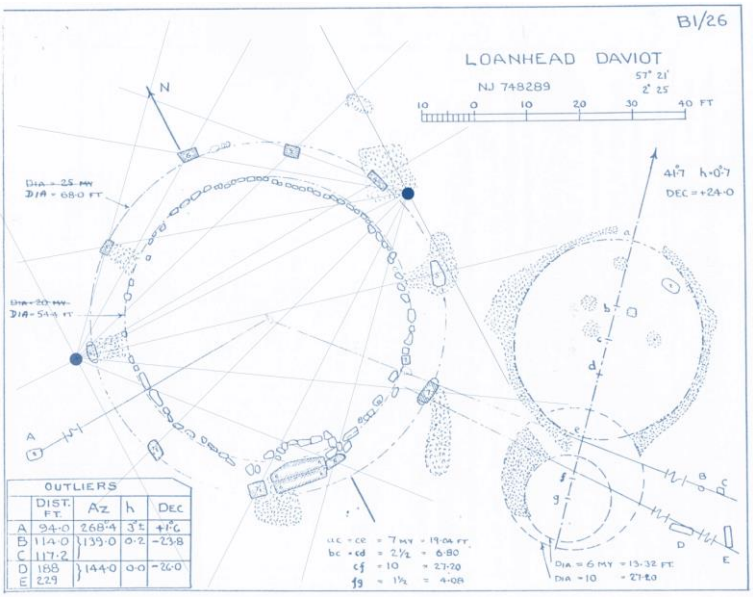

N
10 0 10 20 30 FT
57°12·6
2° 14·0
TYREBAGGER
NJ 859132
B2/1

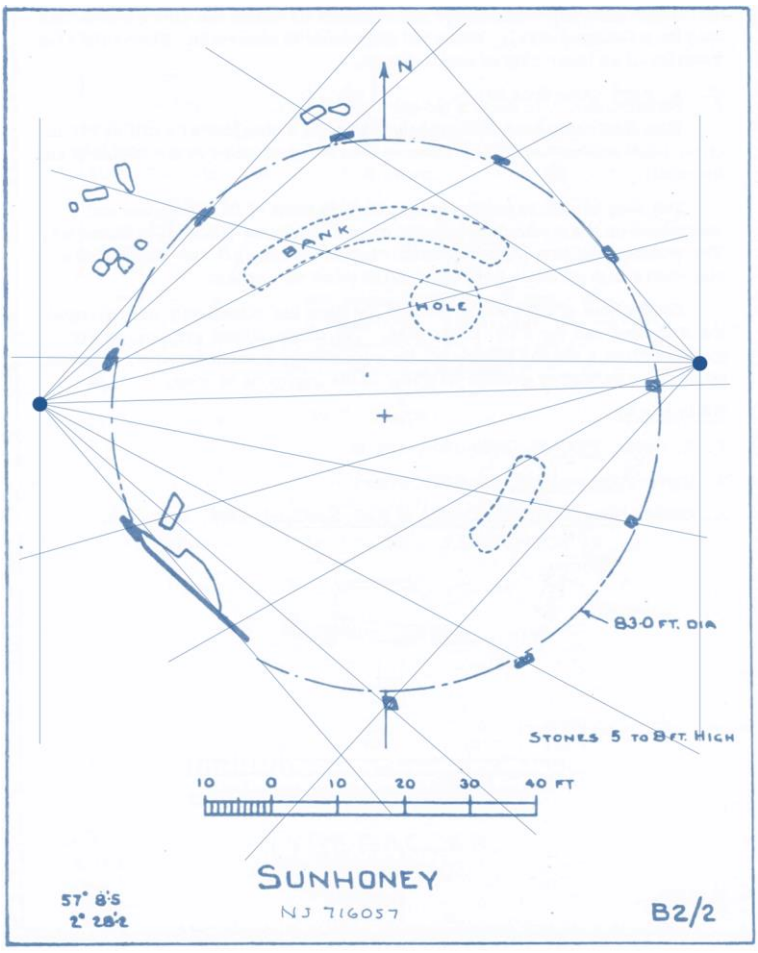

N
ELLIPSES DRAWN
Major Axes 8½ 3¾ MY
Bet. Foci 4¼ 1⅝ MY
Minor Axes 7⅜ 3⅜ MY
10 0 10 FT
CULLERLIE
NJ 785043
B2/7

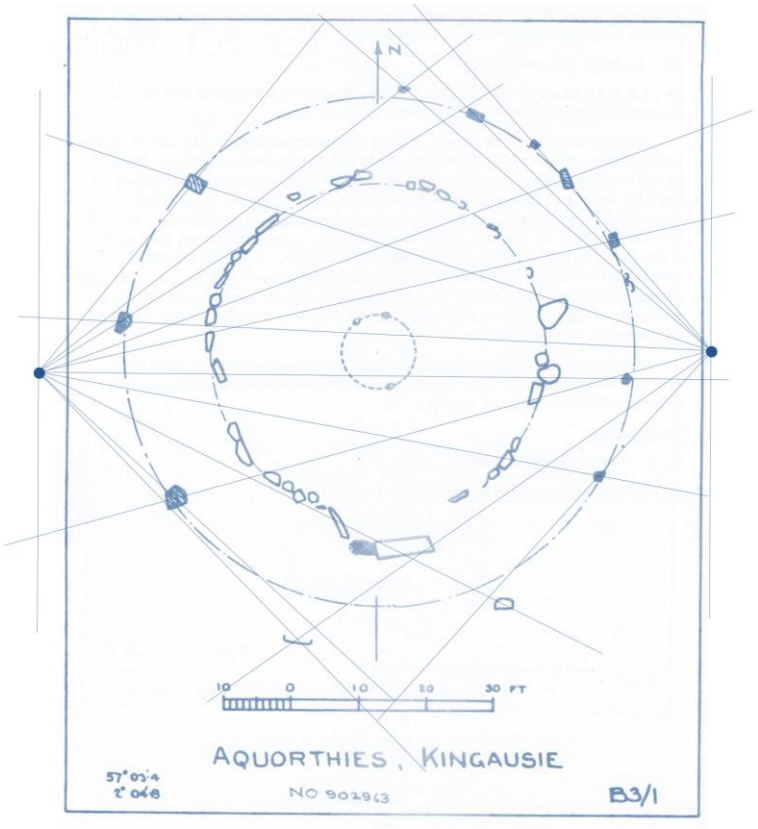

N
0
10
20
FEET
To D
To ⊙
To C
To B
A
44 Ft. Dia.
249°
280°
324°
1°
31°
75°
113°
159°
202°
Azimuths from Centre
STONES VIEWED FROM CENTRE
MAIN CIRCLE
NM 618251

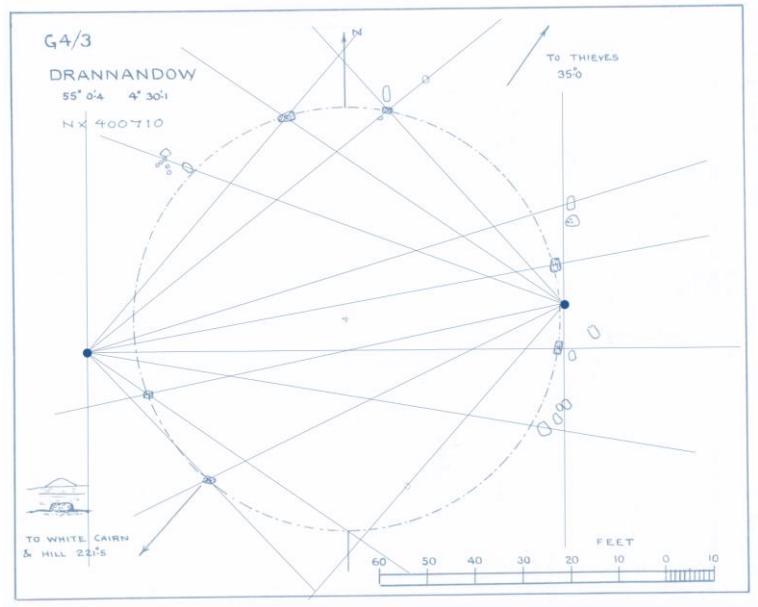

N
49·4 FT. DIA
10 0 10 20 30 FT
LEYS OF MARLEE
NO 160439
P2/1

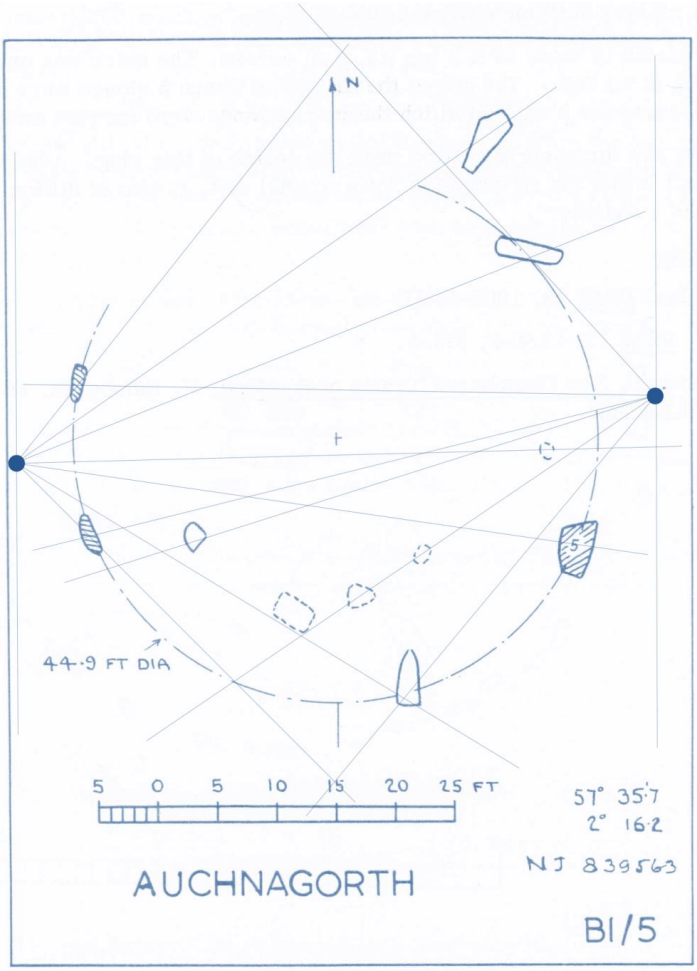

N
10 0 10 20 FT
BLINDWELLS
56° 28·0
3° 25·2
NO 125314
P2/3
N
COLEN
56° 27·8
3° 26·6
NO 110311
P2/6


B1/26
LOANHEAD DAVIOT
NJ 748289
57° 21'
2° 25
10 0 10 20 30 40 FT
N
DIA = 25 MY
DIA = 68·0 FT
DIA = 20 MY
DIA = 54·4 FT
41h 7 h=0h7
DEC = +24·0
OUTLIERS
DIST. FT.
Az
h
DEC
A 94·0 268·4 3h 5 +1·6
B 114·0 139·0 0·2 -23·8
C 117·2
D 188 144·0 0·0 -26·0
E 229
uc = ce = 7 MY = 19·04 FT.
bc = cd = 2½ = 6·80
cf = 10 = 27·20
fg = 1½ = 4·08
DIA = 6 MY = 13·32 FT.
DIA = 10 = 27·20


N
BANK
HOLE
83·0 FT. DIA
STONES 5 TO 8 FT. HIGH
10 0 10 20 30 40 FT
SUNHONEY
NJ 716057
57° 8·5
2° 28·2
B2/2


N
10 0 10 20 30 FT
AQUORTHIES, KINGAUSIE
57° 03'·4
2° 04·8
NO 902943
B3/1


G4/3
DRANNANDOW
55° 0'·4 4° 30'·1
NX 400710
N
TO THIEVES
35°0
TO WHITE CAIRN
& HILL 221'·5
FEET
60 50 40 30 20 10 0 10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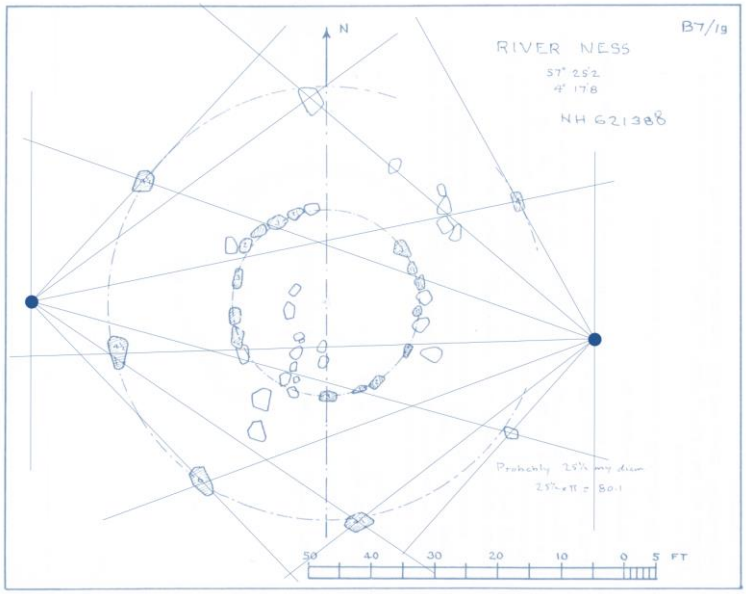
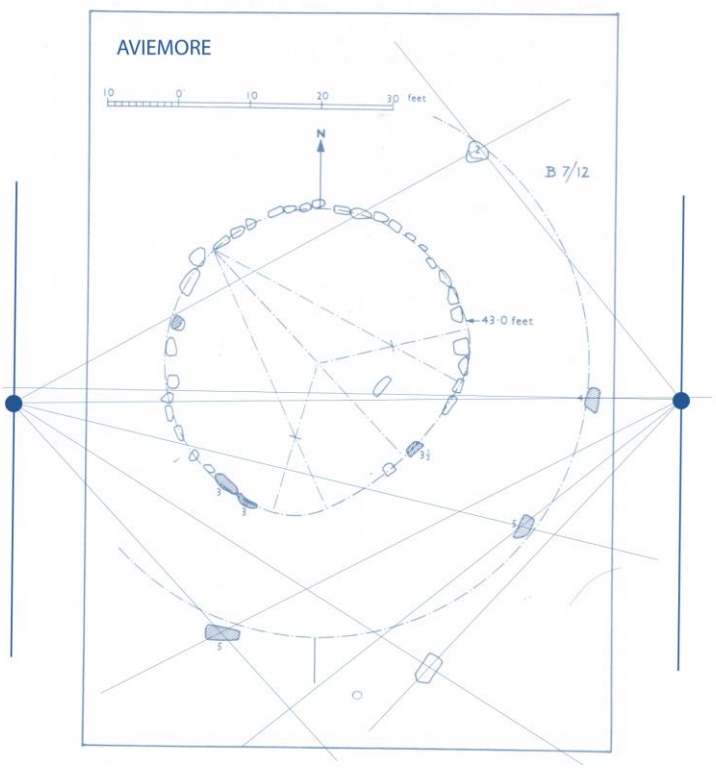
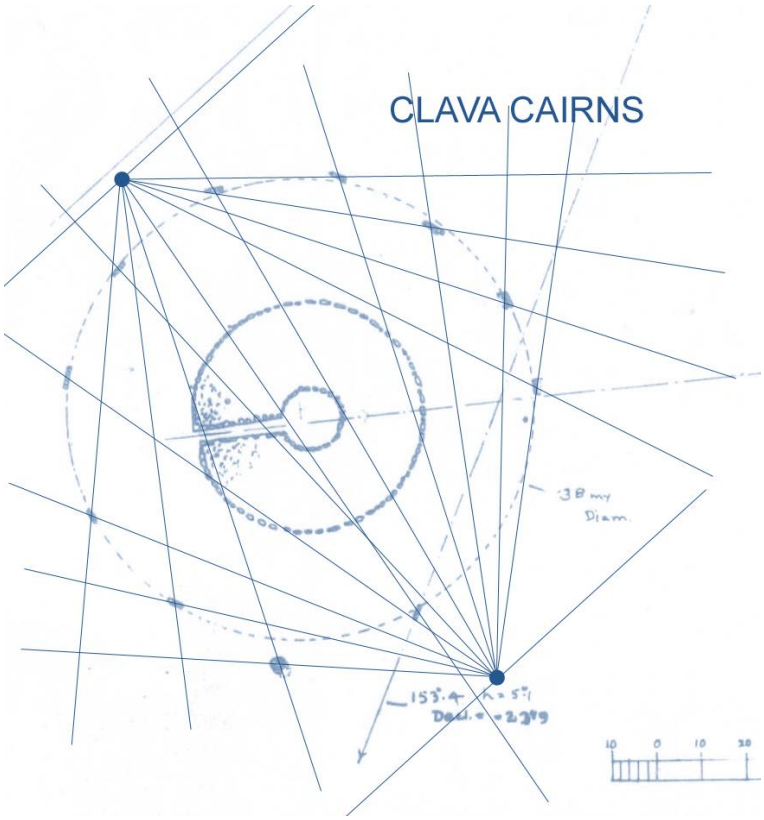
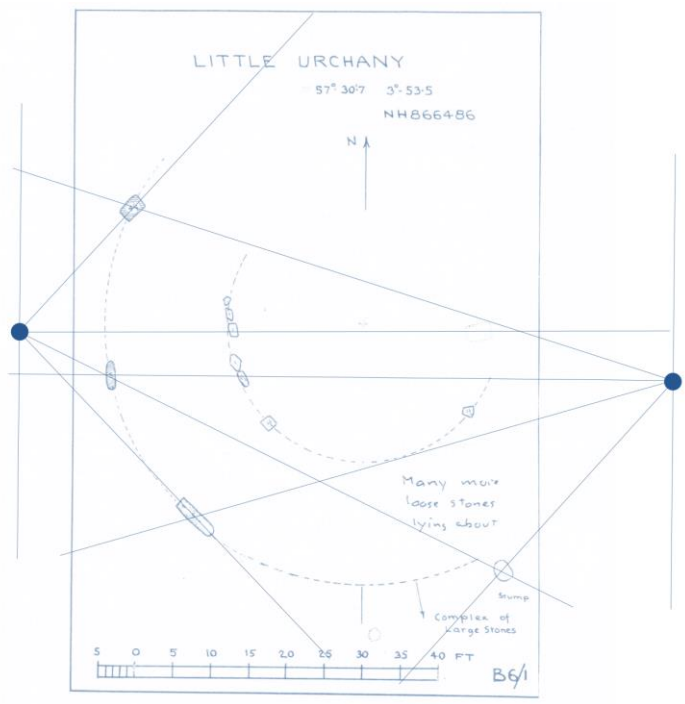
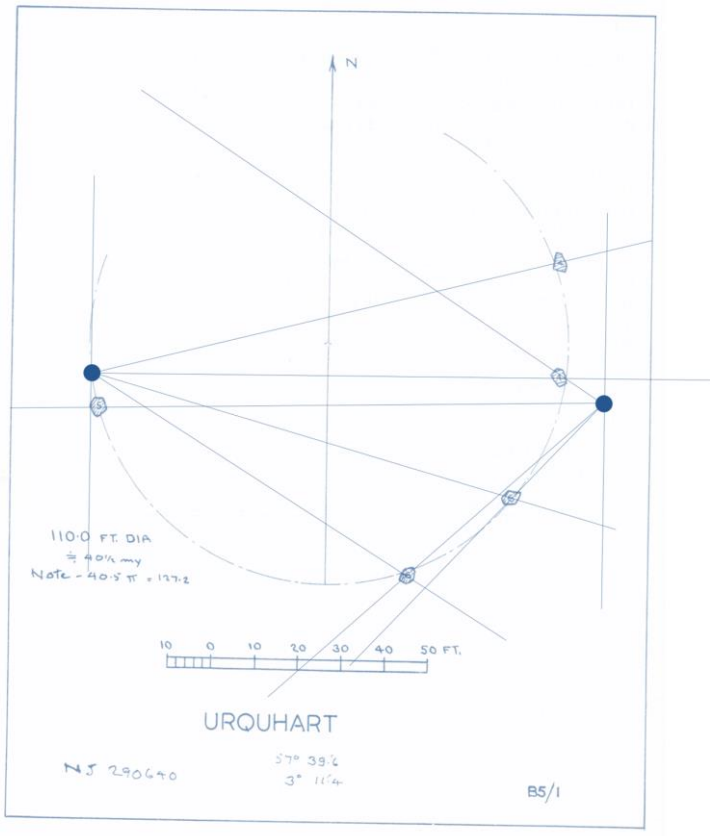
44·9 FT DIA
5 0 5 10 15 20 25 FT
57° 35·7
2° 16·2
NJ 839563
AUCHNAGORTH
BI/5

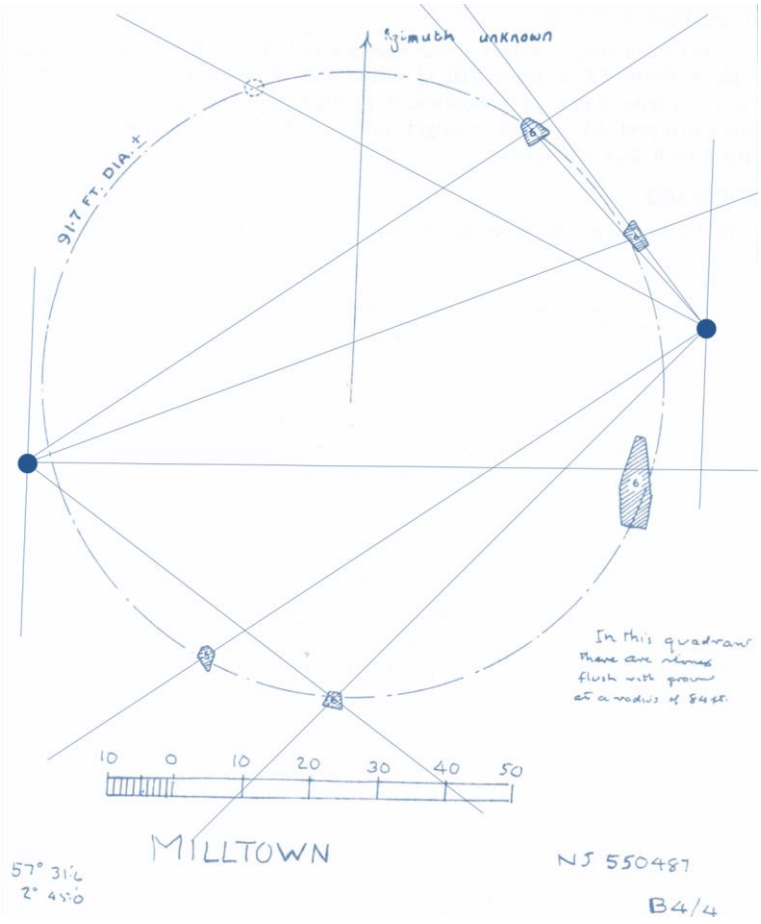

N
B7/19
RIVER NESS
57° 25·2
4° 17·8
NH 621386
50 40 30 20 10 0 5 FT

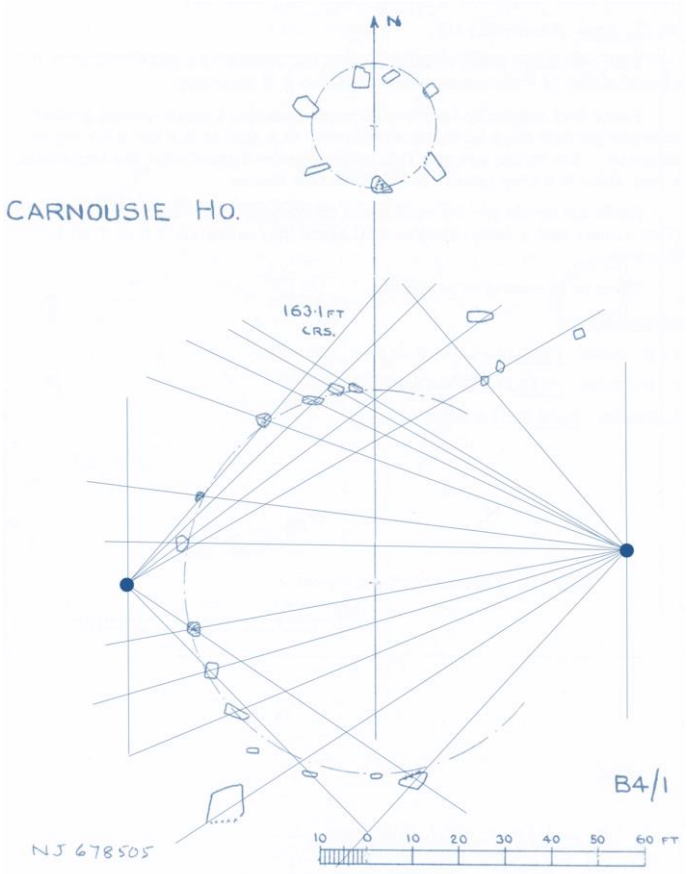

AVIEMORE
10 0 10 20 30 feet
N
B 7/12
43·0 feet

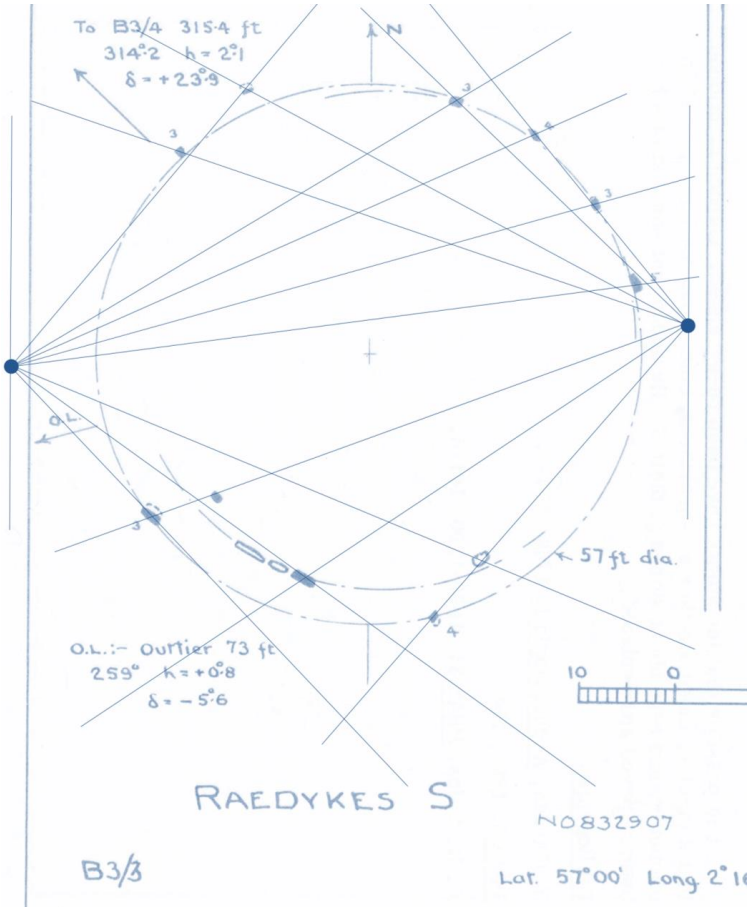

CLAVA CAIRNS
38 my
Diam.

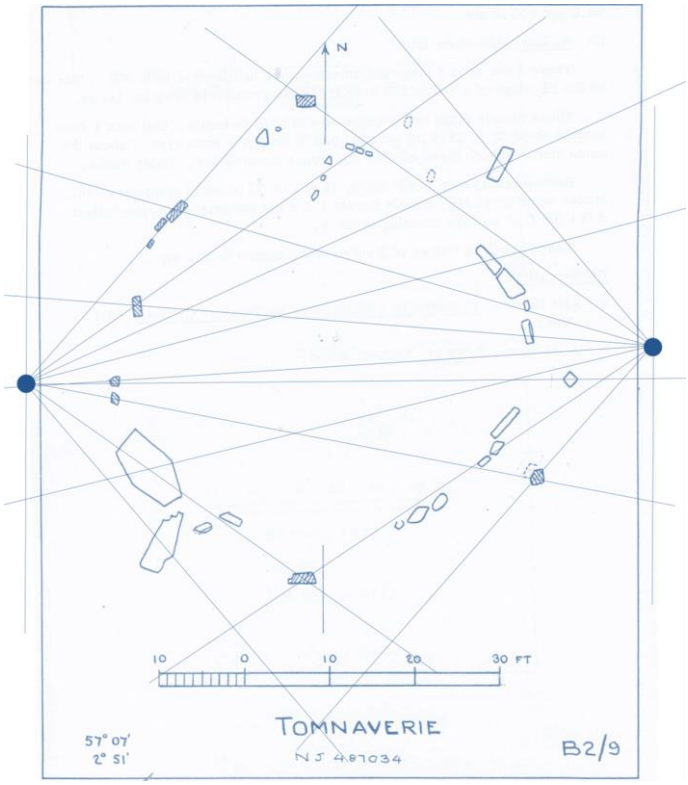

LITTLE URCHANY
57° 30·7 3°-53·5
NH866486
N
Many more loose stones lying about
Stump
Complex of Large Stones
5 0 5 10 15 20 25 30 35 40 FT
B6/1

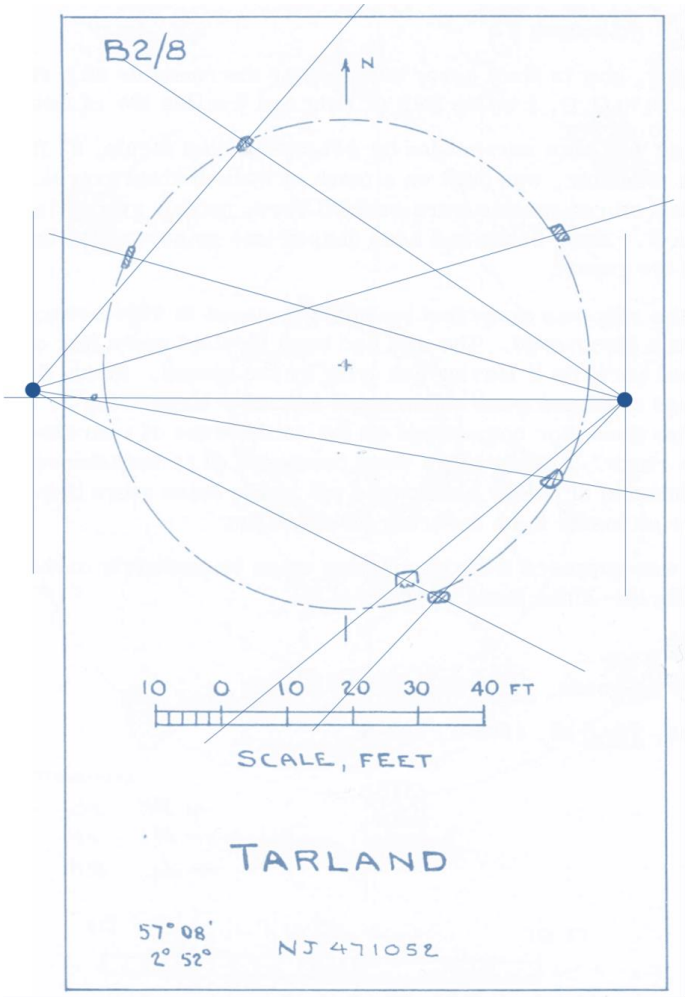

N
110·0 FT. DIA
= 40½ my
Note - 40·5 π = 127·2
10 0 10 20 30 40 50 FT.
URQUHART
NJ 290640
57° 39·6
3° 11·4
B5/1

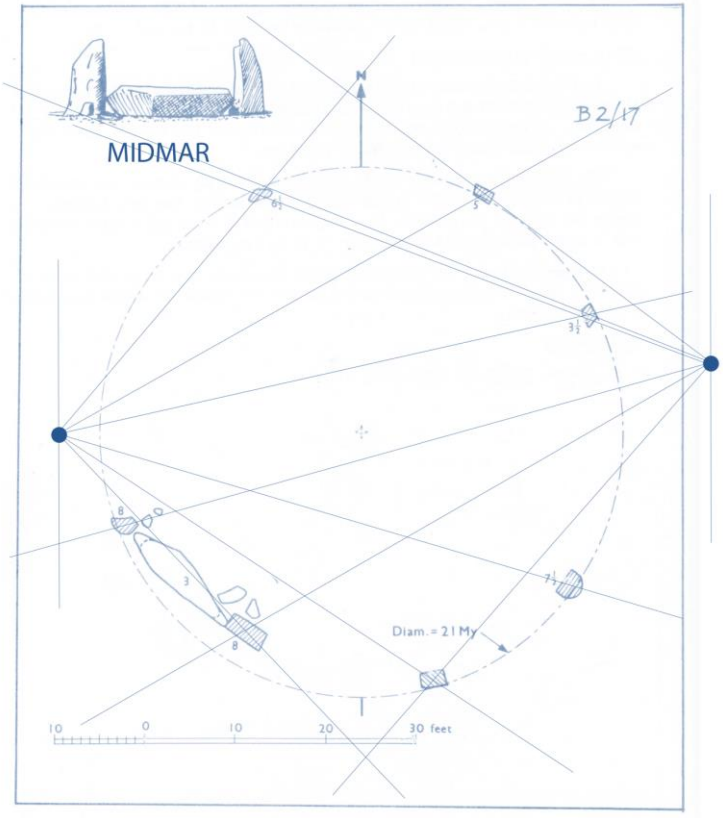

Azimuth unknown
91·7 FT. DIA. ±
In this quadrant there are rebates flush with ground at a radius of 84 ft.
10 0 10 20 30 40 50
MILLTOWN
57° 31·6
2° 45·0
NJ 550487
B4/4

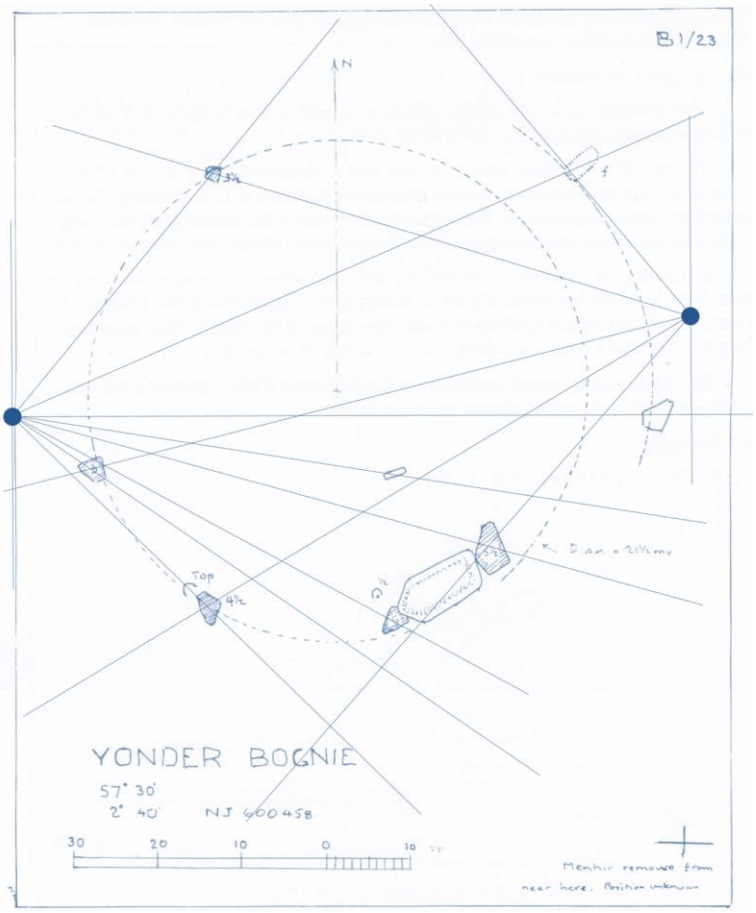

N
CARNOUSIE HO.
163·1 FT
CRS.
B4/1
NJ 678505
10 0 10 20 30 40 50 60 FT

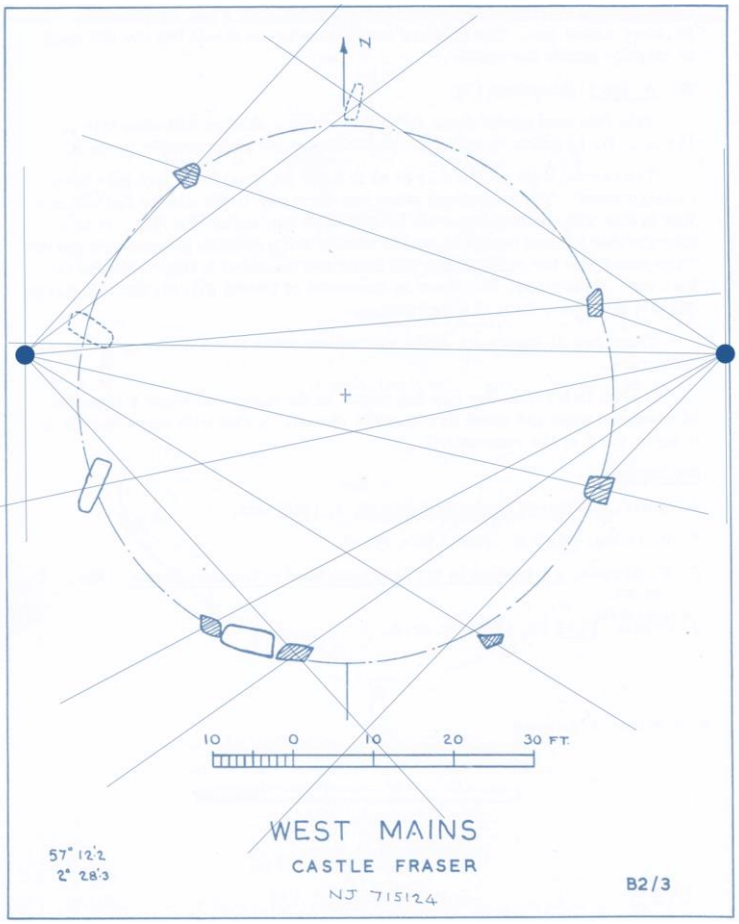

To B3/4 315·4 ft
314°·2 h = 2°·1
δ = +23°·9
N
57 ft dia.
O.L.:- Outlier 73 ft
259° h = +0°·8
δ = −5°·6
10 0
RAEDYKES S
NO832907
B3/3
Lat. 57°00' Long. 2°1

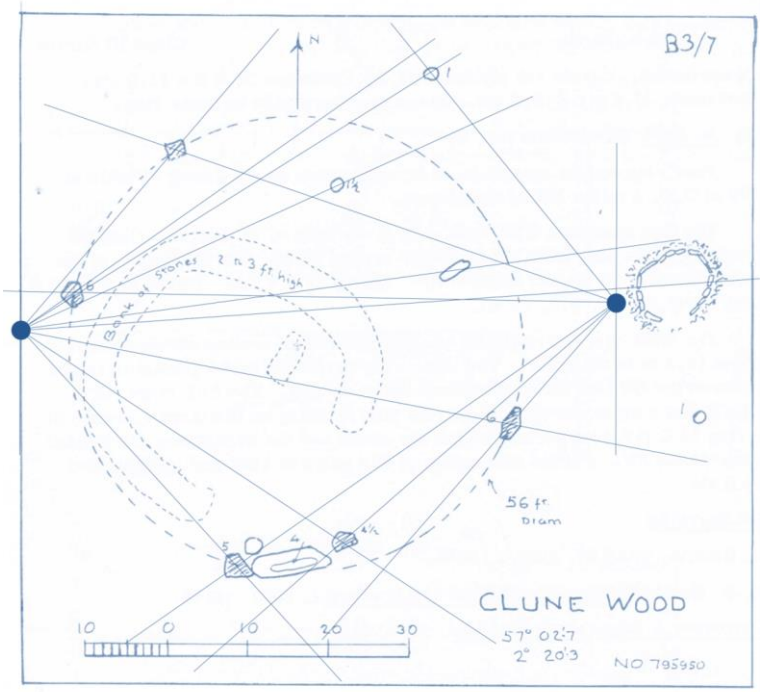

N
10 0 10 20 30 FT
TOMNAVERIE
57° 07'
2° 51'
NJ 487034
B2/9

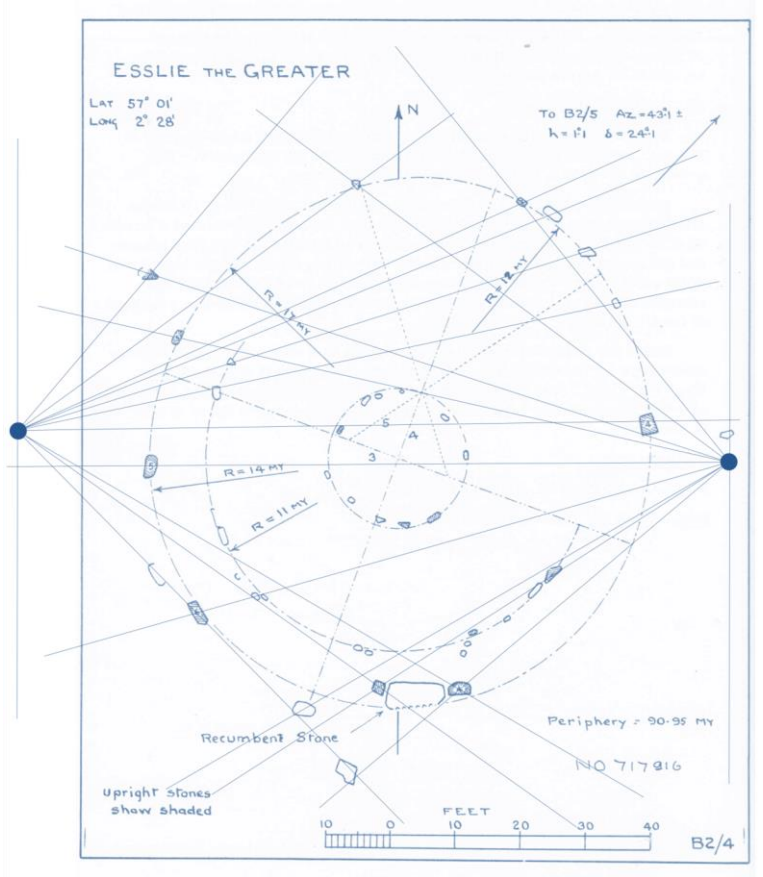

B2/8
N
10 0 10 20 30 40 FT
SCALE, FEET
TARLAND
57° 08'
2° 52°
NJ 471052

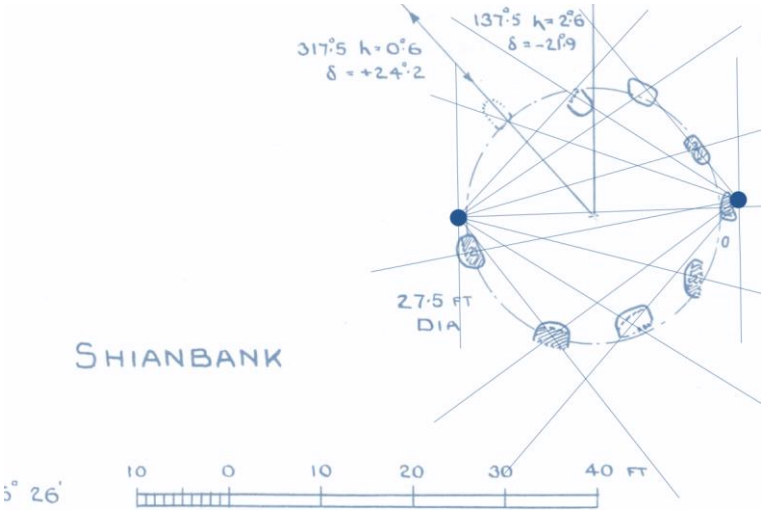

MIDMAR
N
B2/17
Diam. = 21 My
10 0 10 20 30 feet

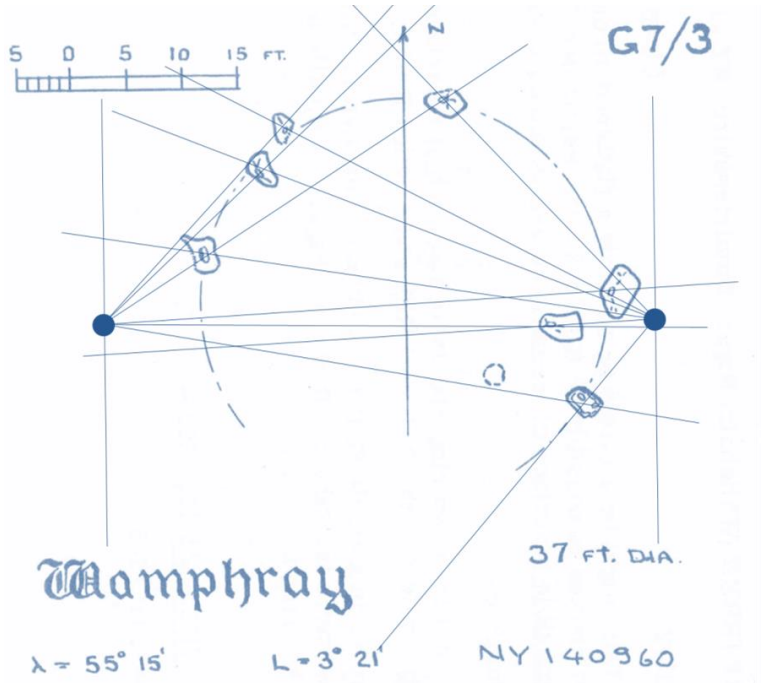

B1/23
N
3½
Top
4½
D¼
K. Diam = 21½ m
YONDER BOGNIE
57° 30'
2° 40'
NJ 660458
30 20 10 0 10 FT
Menhir removed from
near here. Position unknown

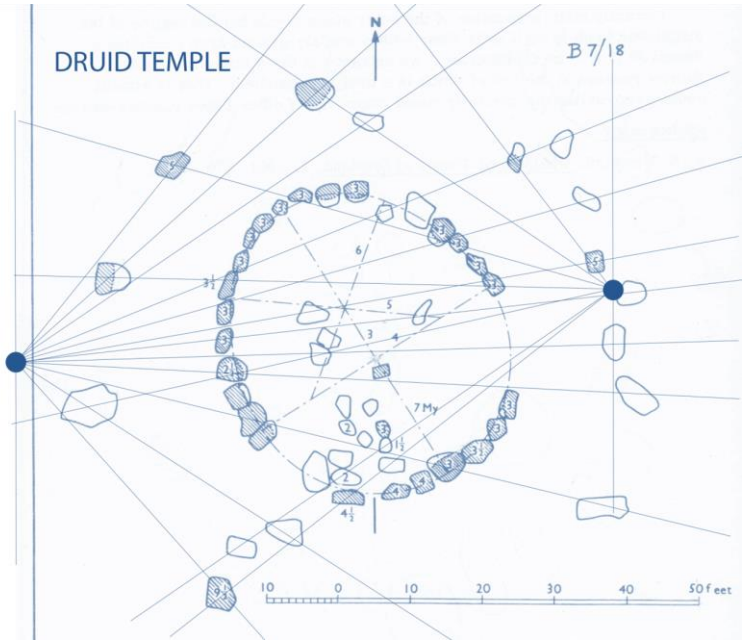

N
10 0 10 20 30 FT
WEST MAINS
CASTLE FRASER
57° 12'2
2° 28'3
NJ 715124
B2/3

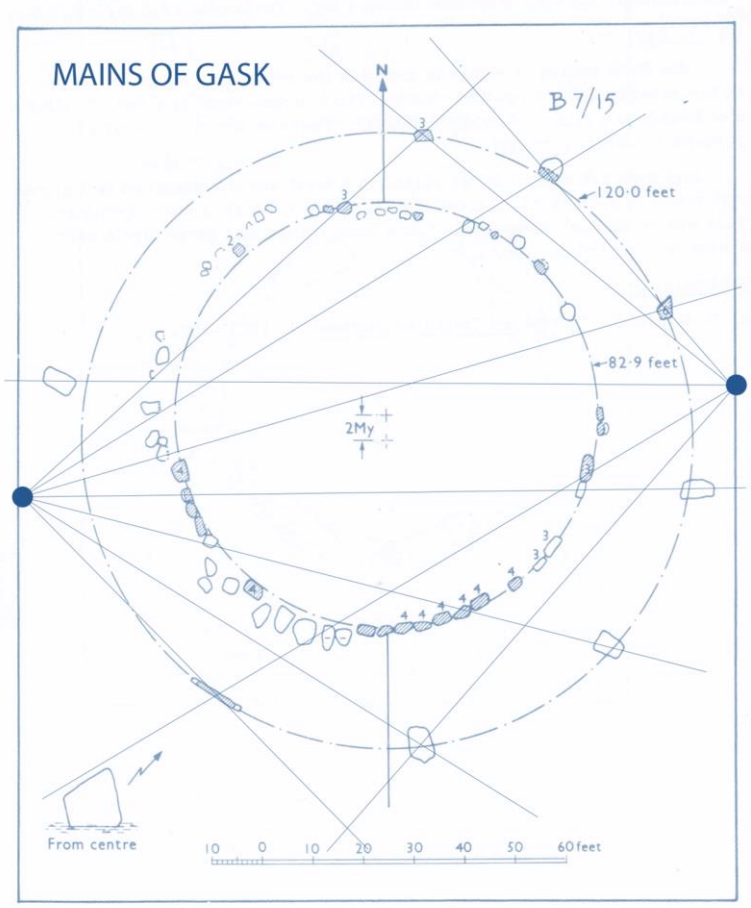

B3/7
N
1
1½
Bank of stones 2 to 3 ft high
56 ft diam
10
CLUNE WOOD
57° 02·7
2° 20·3
NO 795950
10 0 10 20 30

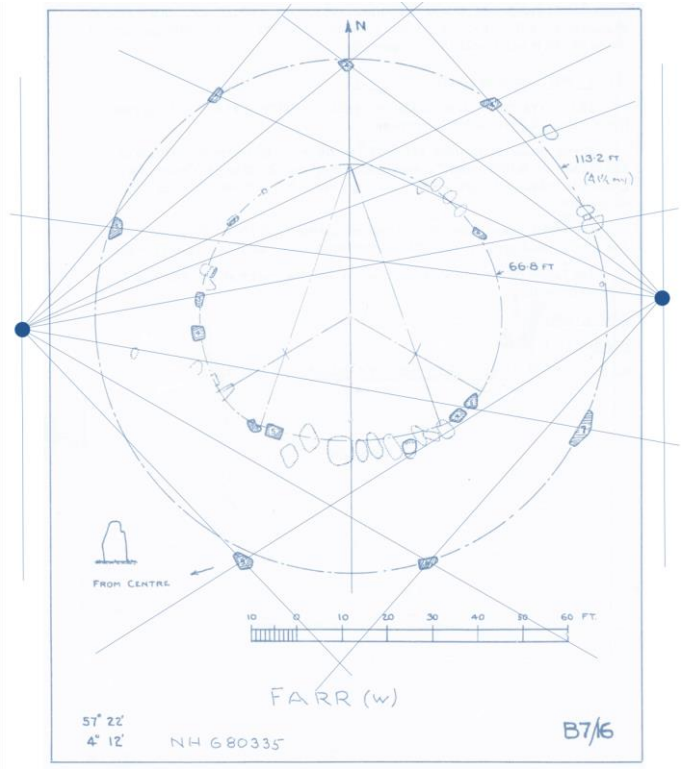

ESSLIE THE GREATER
Lat 57° 01'
Long 2° 28'
N
To B2/5 Az = 43°1 ±
h = 1°1 δ = 24°1
R = 12 MY
R = 14 MY
R = 11 MY
Recumbent Stone
Upright stones shown shaded
Periphery = 90·95 MY
NO 717816
FEET
10 0 10 20 30 40
B2/4

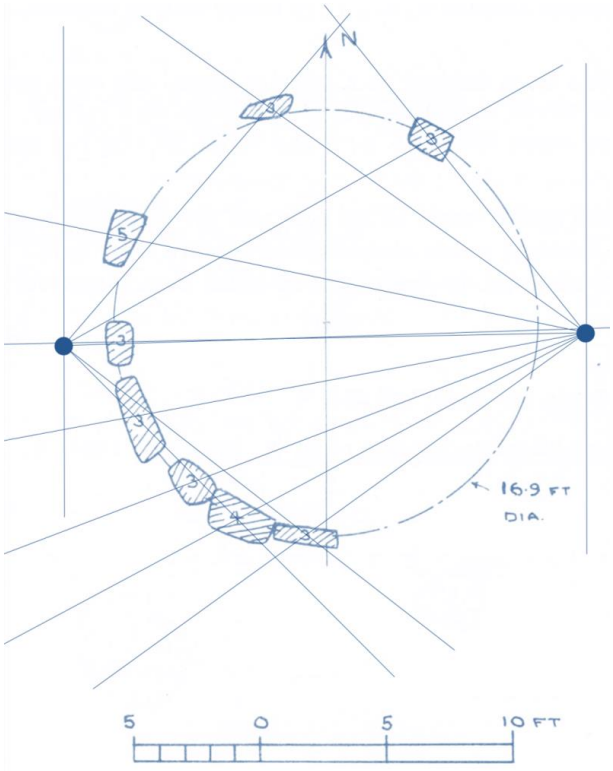

317°5 h=0°6
δ=+24°2
137°5 h=2°6
δ=-21°9
27·5 FT
DIA
SHIANBANK
10 0 10 20 30 40 FT
5° 26'


5 0 5 10 15 FT.
N
G7/3
37 FT. DIA.
Wamphray
λ = 55° 15'
L = 3° 21'
NY 140960


DRUID TEMPLE
B 7/18
N
7My
10 0 10 20 30 40 50 feet


MAINS OF GASK
B 7/15
N
120·0 feet
82·9 feet
2My
From centre
10 0 10 20 30 40 50 60 feet





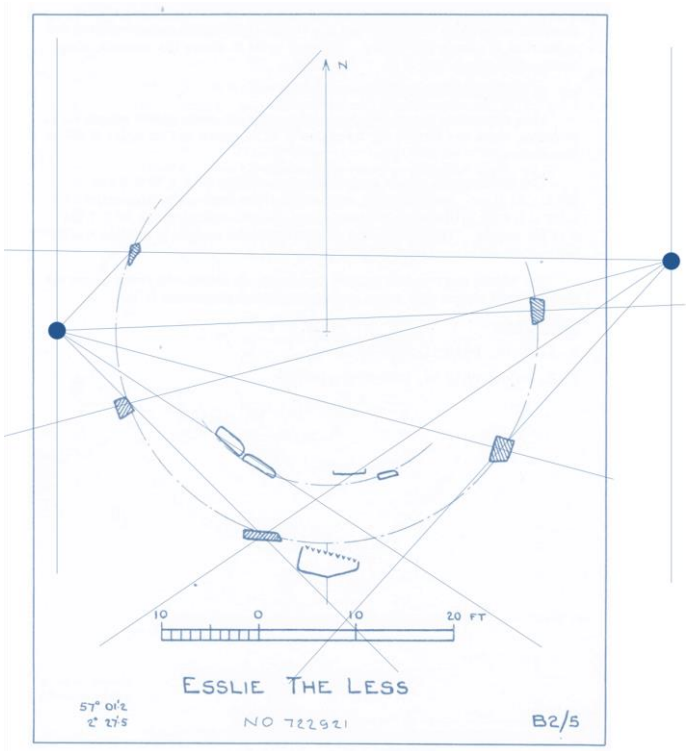
FOUNTAIN HILL

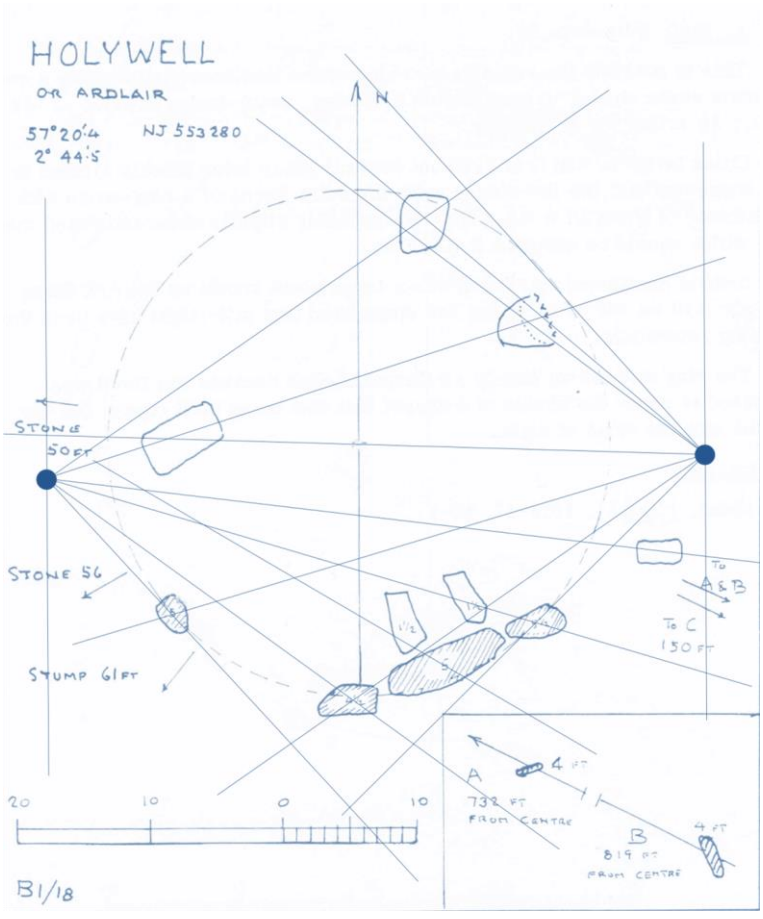
TARVES

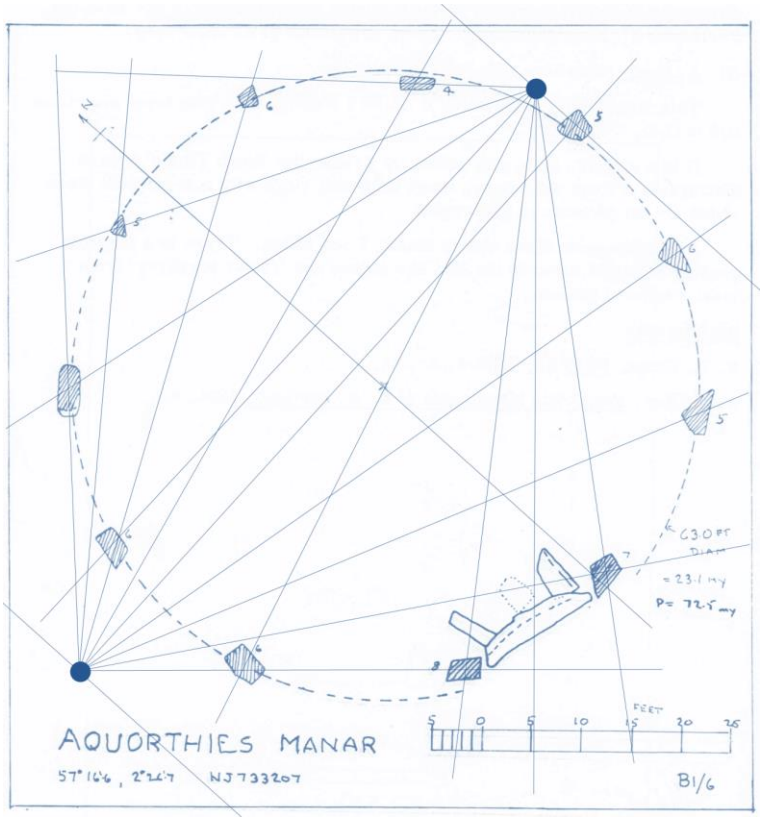
57° 23·1
2° 11·8

NJ 880328

B1/10


N
10 0 10 20 FT
ESSLIE THE LESS
57° 01·2
2° 27·5
NO 722921
B2/5


HOLYWELL
OR ARDLAIR
57°20·4
2° 44·5
NJ 553280
N
STONE 50 FT
STONE 56
STUMP 61 FT
To A&B
To C 150 FT
20 10 0 10
A
4 FT
732 FT FROM CENTRE
B
819 FT FROM CENTRE
4 FT
B1/18


AQUORTHIES MANAR
57°16', 2°24' NJ733207
B1/6
630 FT DIA
= 23.1 my
P = 72.5 my
FEET
5 0 5 10 15 20 25

Appendix III

Period of usefulness of the Stone Circles as Calendrical Devices

The stone circles consist of carefully positioned megaliths that align with the Sun on the horizon at sunrise and sunset on the days of the solstices and equinoxes and days when certain bright stars are aligned due South in the sky at Start of Civil Twilight and End of Civil Twilight. The position of the Sun on the horizon on the days of the equinoxes and solstices remains relatively constant over the period 3200bc to 2400bc so stones aligned with these solar festival days would remain as accurate markers over the 800year period studied. The days on which alignment of the stars due South at civil twilight occurs however changes significantly over the centuries. There is the possibility that the position of the megaliths could be adjusted to take account of the changing alignment. The fact that some of the stones (a,b,f and g) are used to align with the Sun at both sunrise and sunset for different days involving the alignment of different stars means that the direction of movement of each megalith required to allow the circle to maintain its usefulness may be restricted or prevented by the megaliths requirement to align with the Sun on a different festival day. Other stones have different stars aligned at start of civil twilight and end of civil twilight.

The difficulty in adjusting the positions of the stones to maintain the changing alignment of the Sun on the horizon on the days of stellar alignments due South suggests that the stone circles could only be used as an accurate marker for the star festivals for about a century or so before becoming redundant as a marker for the star festival days though the days of the solstices and equinoxes could still be identified. Perhaps the stone circles became redundant around 2900BC either because the stars previously used were no longer important or that another means of identifying the festival days was developed such as a portable device such as the Nebra Disc or of the penannular type of ring that may have involved the alignment of the Sun on the horizon with the long pin on what is typically identified as a brooch but which may have represented a portable calendar using the same principles of alignment as the stone circles.

Stone	Alignment	Start of Civil Twilight		End of Civil Twilight		Adjustment of Megalith position possible after 3000bc
		Day of alignment	Direction of Stone movement required (N=↑,S=↓)	Day of alignment	Direction of Stone movement required (N=↑,S=↓)	
a	1	Summer Solstice Altair Vega	- - -	Summer Solstice Scheat	- -	X
	13	Antares Deneb	↑ ↓	Capella Aldebaran	↓ ↓	
b	2	Deneb Antares	↑ ↓	Capella Aldebarn	↑ ↑	X
	14	Summer Solstice Altair Vega	- - -	Summer Solstice Scheat	- -	
c	3	Spica	↓	Pollux Sirius	↑ ↑	X
d	4	Equinoxes	-	Equinoxes Alphard Regulus	- ↑ ↑	X
e	5	Scheat	↑	Mel-111	↑	√
f	6 8	Betelgeuse Winter Solstice	↓ -	Arcturus Winter Solstice	↑ -	X
g	7 9	Winter Solstice Betelgeuse	- ↑	Winter Solstice Arcturus	- ↓	X
h	10	Scheat	↓	Mel-111	↓	X
i	11	Equinoxes	-	Equinoxes Alphard Regulus	- ↓ ↓	X
j	12	Spica	↑	Pollux	↓	X

Stone a adjustment of megalith to maintain alignment for Antares is northwards but the adjustment for Deneb, Capella and Aldebaran is southwards.

Stone b adjustment of megalith to maintain alignment for Antares is southwards but the adjustment for Deneb, Capella and Aldebaran is northwards

Stone c adjustment of megalith to maintain alignment for Spica is southwards but the adjustment for Sirius and Pollux is northwards

Stone d adjustment of megalith to maintain alignment with Alphard and Regulus is northwards but this cannot be done as the megalith has to maintain its alignment East-West for the Equinox alignments

Stone e adjustment of megalith northwards allows the alignment of Scheat and Mel-111 to be maintained over the centuries except for the fact that the day of Scheat alignment changes at three times the rate of Mel-111.

Stone f adjustment of megalith southwards allows the alignment for Betelgeuse to be maintained but the adjustment needed for the day of alignment of Arcturus to be maintained is northwards

Stone g adjustment of the megalith northwards allows the alignment of Betelgeuse to be maintained but the adjustment needed for the day of alignment of Arcturus to be maintained is southwards

Stone h adjustment of the megalith southwards allows the alignments of Scheat and Mel-111 to be maintained over time though again the rate of change of bearing for Scheat is much greater than Mel-111

Stone i adjustment of the megalith southwards would allow the alignment with Alphard and Regulus to be maintained but at the expense of the equinox alignments

Stone j adjustment of the megalith northwards would allow the alignment for Spica to be maintained but the adjustment for the Pollux alignment to be maintained is southwards.