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A Monte Carlo analysis of the Merrivale stone rows

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There are about sixty stone rows on Dartmoor, single, double and triple, varying in length from 30m to over 3 km. Thom's work suggested the possibility that the rows might be linked with astronomical observations even if they were not apparently oriented to the rising or setting of the sun or moon and it was to explore this that Alan Penny and John Edwin Wood (Wood 1978) surveyed the Merrivale stone rows in 1974.

Merrivale is a very diverse site with rows, cairns, megaliths and circles. It is on the summit of a flat-topped bluff. There are two double rows, denoted Row I and Row II, oriented roughly East-West and almost parallel, and a short single row, Row III, at an angle of about 60 degrees to the longer ones. There several small cairns at the site, usually regarded as Beaker graves, and the stones at one end of Row III are set into a cairn so it seems likely that Row III at least was not built earlier than the Beaker period. The lengths of the three rows are 181.7m, 263.7m and 42.3m. Most of the stones in Rows I and II are quite small but there are larger stones at the ends and at apparently random intervals along the rows. Row III has larger stones only at the ends.

The distances of the larger stones of Row I and Row II from the western ends are given in Table 12.1 (the letters are from Wood). Thus there are ten interstone distances in Row I and 45 in Row II. Wood observed that certain distances appear to be repeated several times—for example AV and DP differ by only 0.2m. Table 12.2 (Wood's Table 7.2) gives 9 matches between distances in Row I with distances in Row II to within 2.4m and also three pairs of distances from Row II, a total of 15 matches. Moreover the repeated distances seem to be close to simple multiples of the three basic lengths:

$$\alpha = 13.1, \beta = 15.6 \text{ and } \gamma = 43.4$$

Wood regarded the figures in Table 12.2 as sufficiently remarkable but in fact the number of matches is much greater. I looked for pairs of distances d_i, d_j from the 55 interstone distances in Row I and Row II together such that

$$\text{either } |d_i - m * d_j| \leq D \text{ or } |m * d_i - d_j| \leq D$$

for some m. There are 90 such coincidences with $D = 1.0$ though not all these would be regarded as 'simple' multiples—for example 263.7 differs by only 0.5m from 28*9.4.

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Row I		Row II	
A	0.0	C	0.0
V	26.9	S	67.9
W	124.9	T	111.4
X	168.2	U	124.1
B	181.7	D	133.6
		P	160.3
		O	175.0
		Q	191.1
		R	237.6
		E	263.7

Table 12.1: Positions of the stones in Row I and Row II

Row I		Row II			
XB	13.2	TU	12.7		
AV	26.9	DP	26.7	RE	26.1
WX	43.3	ST	43.5		
WB	56.5	SU	56.1		
		TO	63.5	OR	62.5
		SD	65.6	UQ	66.8
		DR	103.8	PE	103.3
AW	124.9	CU	124.1		
VX	141.3	UE	139.4		
VB	154.5	TE	152.1		
AX	168.2	SR	169.4		

Table 12.2: Matches between distances in Row I and Row II

D	$m = 1$	$m \leq 9$	
0.5	4	19	Row I–Row II only
1.0	7	30	
1.5	10	39	
2.0	13	52	
2.5	14	63	
0.5	5	44	Both rows
1.0	10	84	
1.5	18	125	
2.0	25	154	
2.5	31	189	

Table 12.3: Observed matches between distances

It seems more reasonable to limit the value of m to $m \leq 9$, which is the largest multiple that Wood considered. Taking separately the cases m=1 (*i.e.* simple coincidences) and $m \leq 9$, and counting either matches between Row I and Row II or matches among all 55 distances for various values of D I obtained the figures in Table 12.3.

Wood thought the number of matches so large that it indicated some intention on the part of the megalith builders and justified a search for the reason they might have had for setting out the site in this way. One possibility is that the repeated distances had a special significance for them and were honoured by repetition. Wood describes a method of extrapolating observations to find the moon's maximum declination that depends on a fixed reference G that is a characteristic of each site. For example one of the distances at Temple Wood is close to $4G$ and Professor Thom has suggested that this might be a permanent reference for purposes of extrapolation. The value of G at Merrivale (the average over the two rows) is 15.3 and this is close to the value of β, so the possibility that Merrivale was a lunar observatory is at least worth considering, even if the use of repetition seems an odd way of recording a reference measurement. The important question, then, is to decide whether or not the number of matches found is indeed remarkable. If it is not then there is no need to look for an explanation.

Douglas Heggie (Heggie 1981) noted that the largest difference in Wood's Table 7.2 is 2.4m and gave an estimate of the probability of finding a Row II distance within 2.4m of at least one of the Row I distances as

$$10 \times 2 \times 2.4/263.7 = 0.18$$

and so the expected no of matches between the two rows is

$$0.18 \times 45 = 8$$

which is close to the actual number observed (*i.e.* the number in Table 12.2), viz 9. Heggie concludes that there is no significance in the matches between pairs of distances. The argument is flawed both because the 45 distances in Row II are not independent (with the ends fixed there are only 8 choices for the remaining stones) and because the number observed is not 9 but 14 (Table 12.3). What is wanted is an empirical method which provides some guidance as to the appropriate level of amazement. I have adopted a simple Monte Carlo method, generating a large number of Merrivales

Row I matched with Row II				Both rows combined			
$D = 1.0$ $m = 1$		$D = 2.4$ $m = 1$		$D = 1.0$ $m = 1$		$D = 1.0$ $m \leq 9$	
No	Freq	No	Freq	No	Freq	No	Freq
0	18	0	0	0	0	<55	47
1	72	2	4	2	1	60	98
2	144	4	36	4	22	65	137
3	201	6	120	6	74	70	164
4	208	8	222	8	133	75	146
5	151	10	279	10	188 ⇐	80	134
6	96	12	179	12	151	85	97 ⇐
7	53 ⇐	14	96 ⇐	14	131	90	67
8	29	16	42	16	99	95	40
9	17	18	15	18	76	100	20
10	5	20	5	20	52	105	16
11	3			22	31	110	8
12	2			24	21	115	4
13	0			26	15		
				28	8		

Table 12.4: Frequency distributions of matches

and counting the number of matches found. The total number of sites generated which have more matches than the number observed is then a good indication of the chance that the observed number arose from a purely random choice of positions for the stones. The method is simple, avoids delicate probabilistic reasoning and can be implemented on rudimentary computing equipment.

I considered only Row I and Row II, kept the lengths fixed and placed the remaining large stones at random positions along the rows. I then counted the number of matches with various values of the matching criterion D, both with $m = 1$ and also allowing values of m up to $m \leq 9$. Each run generated 1000 sites and the frequencies given in the tables are the averages of 5 runs; the precision of the frequencies may be estimated roughly from the variance of the 5 sample values. For example in Table 12.4 the value 208 is the mean of 5 values whose standard error is 11.6.

In Table 12.4 the first of each pair of columns is the number of matches per 1000 and the second is the frequency.

The arrows indicate the actual counts from Table 12.3. They are somewhat higher than the distribution means for the matches between Row I and Row II; for example for D = 1.0 the frequency of 7 or more matches is only 109 out of 1000. When both rows are considered together, though, the observed value is close to the mean of the distribution. If the intervals between the stones were almost equal the variance of the distances would be smaller than expected so the Monte Carlo frequency counts of variances is a direct measure of non-randomness. Table 12.5 gives frequency counts of the variances of distances between adjacent stones in 5000 generated sites. The arrows show the observed variances.

Wood also noticed that there are a number of distances that are multiples of $G = 15.3$. I counted the number of matches between the observed 55 distances and multiples (up

Var	Frequency		
	Row I	Row II	
0	44	21	
200	90	203	
400	117	284	⇐
600	124	197	
800	112	126	
1000	101 ⇐	75	
1200	82	39	
1400	67	21	
1600	53	14	
1800	46	7	
2000	33	5	
2200	27	3	
2400	19	2	
2600	16	2	
2800	16		
3000	11		

Table 12.5: The distribution of variances

No	Frequency
0	4
1	31
2	90
3	161
4	211
5	189
6	134
7	85
8	48
9	24
10	13
11	5 ⇐
12	2
13	1

Table 12.6: Frequency counts of matches with X = 15.3 ($D = 1.0, m \leq 9$)

to m=9) of X for values of X between 2 and 30. The values in the neighbourhood of 15.3 are

X	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9
Freq	6	6	3	3	6	8	11	10	9	10	9	4

There are more matches in the range 15.4–15.8 than for other values and the value of 11 is equalled only at $X = 7.1$, which is not surprising since this is a sub-multiple.

The frequency distribution of matches with multiples of 15.3, over both rows with $D = 1.0$ and $m \leq 9$, is given in Table 12.6. The number of matches was 11 or more in only 45 cases out of 5000 so the observed number is near the tail of the distribution. This result is intriguing; if I had set out to look for the greatest number of matches and found it to be 11 then there would be nothing odd about this occurring with a low frequency but instead I started with the constant value $G = 15.3$ and to find this value (or strictly its neighbour 15.4) generating the greatest number of matches was unexpected.

I conclude that the number of repetitions of distances or multiples of distances in the two long rows at Merrivale is not significantly different from expectation but the distances do appear to match multiples of $G = 15.3$ with a frequency somewhat greater than would be expected. I think the question whether Merrivale may have been a lunar observatory must remain open.

References

HEGGIE, D. C. 1981. *Megalithic Science*. Thames & Hudson.

WOOD, J. E. 1978. *Sun, Moon and Standing Stones*. OUP.