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CIRCUMFERENTIAL VARIABILITY OF RELATIVE DENSITY IN LODGEPOLE PINE

by

J.S. Gonzalez
Scientist
Wood Science

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Project Leader

Department Manager

NOTICE

SUMMARY

The circumferential variability of relative density was examined in nine lodgepole pine discs taken at breast height to determine if the present method of analyzing two opposite increment cores is sufficient for estimating the mean density of the stem at breast height. Results showed that two samples taken at 180 degrees to each other give better results than three to four samples randomly taken at breast height.

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1.0 INTRODUCTION

The variability of relative density in lodgepole pine stem wood has been widely studied (Bjorklund, 1982; Tackle, 1962; Taylor *et al.*, 1982; Singh, 1984). Most of these studies, however, examined either vertical or radial variability. Circumferential variability has not been studied as widely even though differences in wood structure according to direction might be expected as a response to wind or solar exposure (Liese *et al.*, 1959). Reck (1966) examined the effect of direction on wood structure of pine. He concluded that among control trees, direction has no effect on the structure. Cown (1971) analyzed circumferential variation in the wood density of radiata pine and Douglas-fir in new Zealand. He suggested that circumferential variations are unpredictable and to get a good estimate of breast-height density for individual trees, three to four cores per tree would be necessary.

Forintek has received lodgepole pine breast-height discs from parent trees selected by the B.C. Ministry of Forests for the purpose of assessing their wood relative density. The availability of these discs presented an opportunity to do exploratory work on the circumferential variability of breast-height density of lodgepole pine, heretofore arbitrarily assessed on the basis of two increment cores per tree. The objective is to find out if the present method of analyzing two breast-height cores per tree, taken at 180 degrees to each other, is sufficient to characterize the relative density of the tree at breast height.

2.0 STAFF

J.S. Gonzalez	Scientist Wood Science Department
R.M. Kellogg	Manager Wood Science Department

3.0 MATERIALS AND METHODS

Originally, it was intended to take five discs to represent slow and fast growth trees from two different provenances. It was difficult, however, to find discs entirely free of knots or compression wood. This dictated the number of discs finally analyzed.

A total of nine discs were used. Four were from provenance 42, near Champion Lake, Castlegar; three were from provenance 72 and two were from provenance 14, near Salmon Arm and Kamloops, respectively. A description of the discs is given in Table 1.

The discs were cut as shown in Figure 1. The number of wedges from each disc ranged from 12 to 17, depending on the size of the disc. The wedges were divided into an inner half: the portion from the pith to half the radial distance, and an outer half: the portion from half the radial distance to the cambium. This was done because Forintek has been assessing relative density of increment cores which are similarly divided into an inner and outer half to obtain a separate estimate of the juvenile wood (inner half) and the mature wood (outer half) density.

The wedges were aspirated in water under alternate vacuum and pressure until they reached the fully swollen, green volume condition. The volumes were measured by water-displacement and the oven-dry weights were taken after drying the samples in an oven at 105°C. Density was calculated as the ratio of the oven-dry weight to the volume of the sample.

The variances within each disc were calculated separately for the inner and outer half wedges. Using these variances, the 95 percent confidence limits for the mean were calculated based on different number of samples taken at random from the disc. The following formula was used:

$$\text{95\% confidence limits for the mean} = \frac{\text{1.96 x square root of disc variance}}{\text{square root of number of samples}}$$

The constant 1.96 was used on the assumption that the distribution of relative density within the disc is normal. The 95 percent confidence limits for the mean were calculated for the following sample sizes per disc: 1) one; 2) two; 3) three; 4) four; 5) two samples taken at 180 degrees to each other.

Table 1

Description of the Discs

Disc Identification	Provenance	Approximate Ring Count at Breast Height	Average Diameter (cm)
14-10	Kamloops	110	21
14-2	"	90	26
42-10	Champion Lake (Castlegar)	90	24
42-11	"	90	24
42-12	"	90	19
42-15	"	90	37
72-1	Salmon Arm	70	18
72-5	"	65	19
72-7	"	90	25

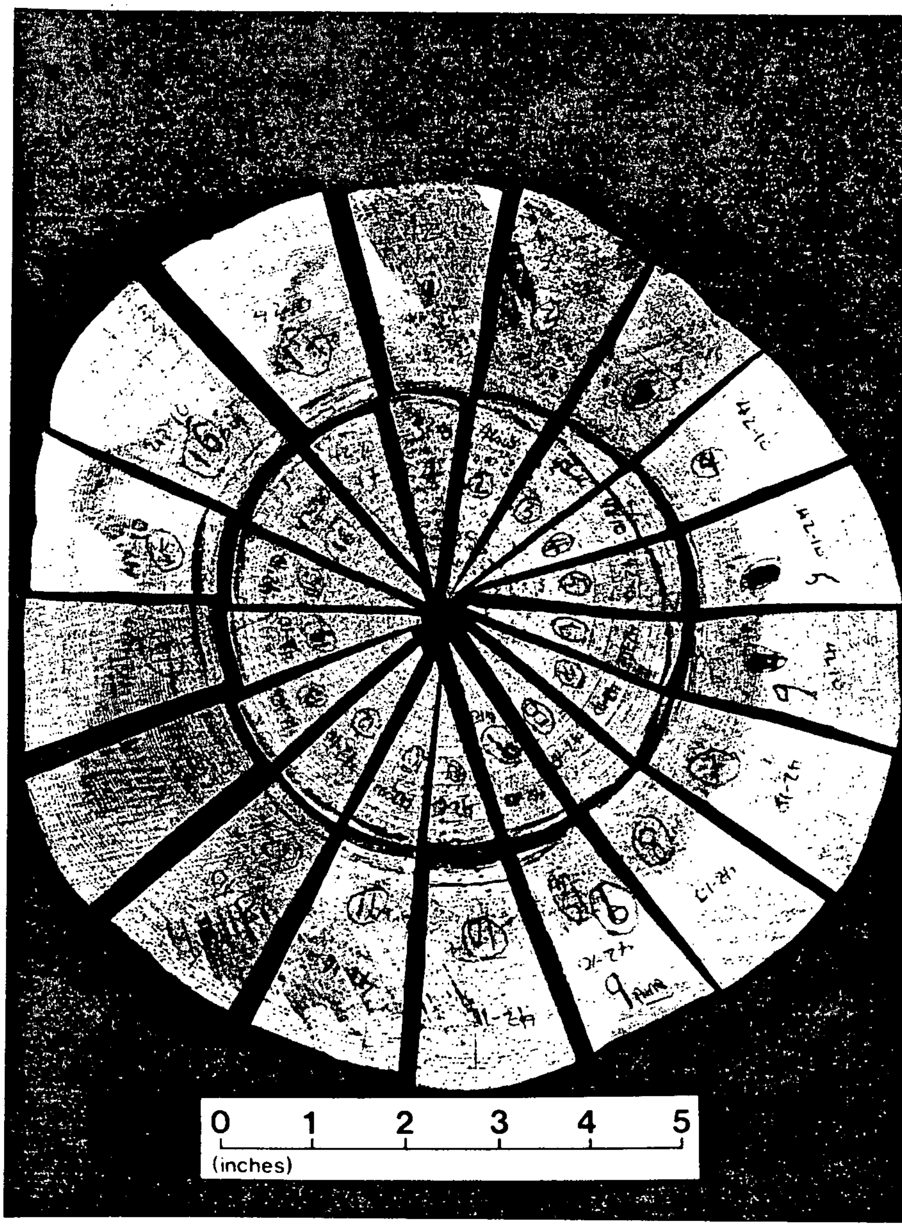

Figure 1. Breakdown of the discs.

4.0 RESULTS AND DISCUSSION

The mean relative density of the inner and outer half samples and related statistics for each disc are presented in Table 2. Generally, the circumferential variation in relative density of the inner half within a disc was lower than that of the outer half, although the highest coefficient of variation was found in the inner half of Disc No.72-1. This disc gave a coefficient of variation of 5.2 percent, which was high compared to the other discs whose coefficient of variation ranged from 1.3 to 3.5 percent. The extractives content of the inner half samples of Disc No.72-1 was analyzed to determine if it was contributing to the high variability. The extractive content of the samples was quite uniform. A mean extractives content of 3.97 percent with a standard deviation of 0.55 percent was obtained. It was therefore concluded that extractive content was not a contributory factor in this case.

The coefficient of variation of the outer half wedges of the discs ranged from 2.6 to 4.4 percent. Cown showed comparable variations in the density of the outermost rings in Douglas-fir. He also found that the first 10 rings from the pith generally had lower variation than the outermost rings.

The density of the wedges within a disc was plotted in Figures 2 to 10 to examine the density gradient circumferentially. Although the range of density values was large, the trend was generally a smooth gradient. In one case, Disc No.14-10, where the density of the inner half exceeded that of the outer half, the inner half wedges were found to contain small knots that escaped notice initially. One side of the disc was also found to have compression wood, which would explain the trend. This also escaped initial notice because the disc was not noticeably eccentric to suggest the presence of compression wood.

The question of how many increment cores should be analyzed, to obtain a reasonable estimate of the breast-height density, was examined. Using the variances for each disc, the 95 percent confidence limits for the mean were calculated on the basis of one, two, three, and four samples taken at random from the disc. It was also calculated for two samples taken at 180 degrees to each other. The 95 percent confidence limits for each disc and the average for all discs for each sampling intensity are shown in Table 3.

Results show that taking two samples at 180 degrees to each other gives better results than taking three or four samples at random. In most of the discs, the 95 percent confidence limits for two samples taken at 180 degrees to each other were less than or equal to the confidence limits for three or four samples taken at random. This is probably explained by the trend shown in Figures 2 to 10 where in many cases, the relative density increased or decreased gradually circumferentially reaching a high and a low on opposite sides of the disc. If two samples were taken opposite to one another, their mean would give a closer approximation of the mean for the whole disc than if three to four samples were taken randomly which could be predominantly from a low or high density side of the disc. One sample is definitely insufficient for obtaining a good estimate of the relative density at breast height.

5.0 CONCLUSIONS

Based on the limited number of discs studied, the following conclusions may be drawn:

1. At breast height, two samples taken at 180 degrees to each other give a better estimate of the relative density of the stem at breast height than three to four samples taken at random.

2. The large variation found in some breast-height stems shows that one core is not sufficient for estimating breast-height relative density.

3. The present method of sampling two increment cores at breast height at 180 degrees to each other is sufficient for estimating the relative density of lodgepole pine at breast height.

Table 2

Mean Relative Density of the Discs
and Related Statistics

Disc Identification		Mean Relative Density	Standard Deviation	Coefficient of Variation (%)
14-10	INNER	0.531	0.019	3.53
	OUTER	0.530	0.023	4.39
14-2	INNER	0.429	0.011	2.56
	OUTER	0.455	0.017	3.63
42-10	INNER	0.359	0.006	1.73
	OUTER	0.399	0.013	3.36
42-11	INNER	0.382	0.005	1.34
	OUTER	0.467	0.012	2.64
42-12	INNER	0.382	0.008	2.09
	OUTER	0.453	0.012	2.58
42-15	INNER	0.408	0.014	3.43
	OUTER	0.436	0.014	3.17
72-1	INNER	0.367	0.019	5.21
	OUTER	0.422	0.016	3.87
72-5	INNER	0.380	0.009	2.31
	OUTER	0.412	0.013	3.15
72-7	INNER	0.429	0.008	1.92
	OUTER	0.458	0.015	3.26

Table 3

95 Percent Confidence Limits for the Mean Based on Number of Random Samples Taken Per Disc and on Two Samples Taken at 180 Degrees to Each Other

Disc Identification	Number of Samples Taken at Random				Two Samples Taken 180 Degrees Apart
	One	Two	Three	Four	
14-10-INNER	0.037	0.026	0.021	0.018	0.019
14-10-OUTER	0.046	0.032	0.026	0.023	0.011
14-2-INNER	0.022	0.015	0.012	0.011	0.006
14-2-OUTER	0.032	0.023	0.019	0.016	0.020
42-11-INNER	0.010	0.007	0.006	0.005	0.004
42-11-OUTER	0.024	0.017	0.014	0.012	0.007
42-15-INNER	0.027	0.019	0.016	0.014	0.018
42-15-OUTER	0.027	0.019	0.016	0.014	0.017
42-10-INNER	0.012	0.009	0.007	0.006	0.005
42-10-OUTER	0.026	0.019	0.015	0.013	0.016
42-12-INNER	0.016	0.011	0.009	0.008	0.006
42-12-OUTER	0.023	0.016	0.013	0.012	0.012
72-1-INNER	0.037	0.026	0.022	0.019	0.015
72-1-OUTER	0.032	0.023	0.018	0.016	0.006
72-7-INNER	0.016	0.011	0.009	0.008	0.013
72-7-OUTER	0.029	0.021	0.017	0.015	0.016
72-5-INNER	0.017	0.012	0.010	0.009	0.008
72-5-OUTER	0.025	0.018	0.015	0.013	0.019

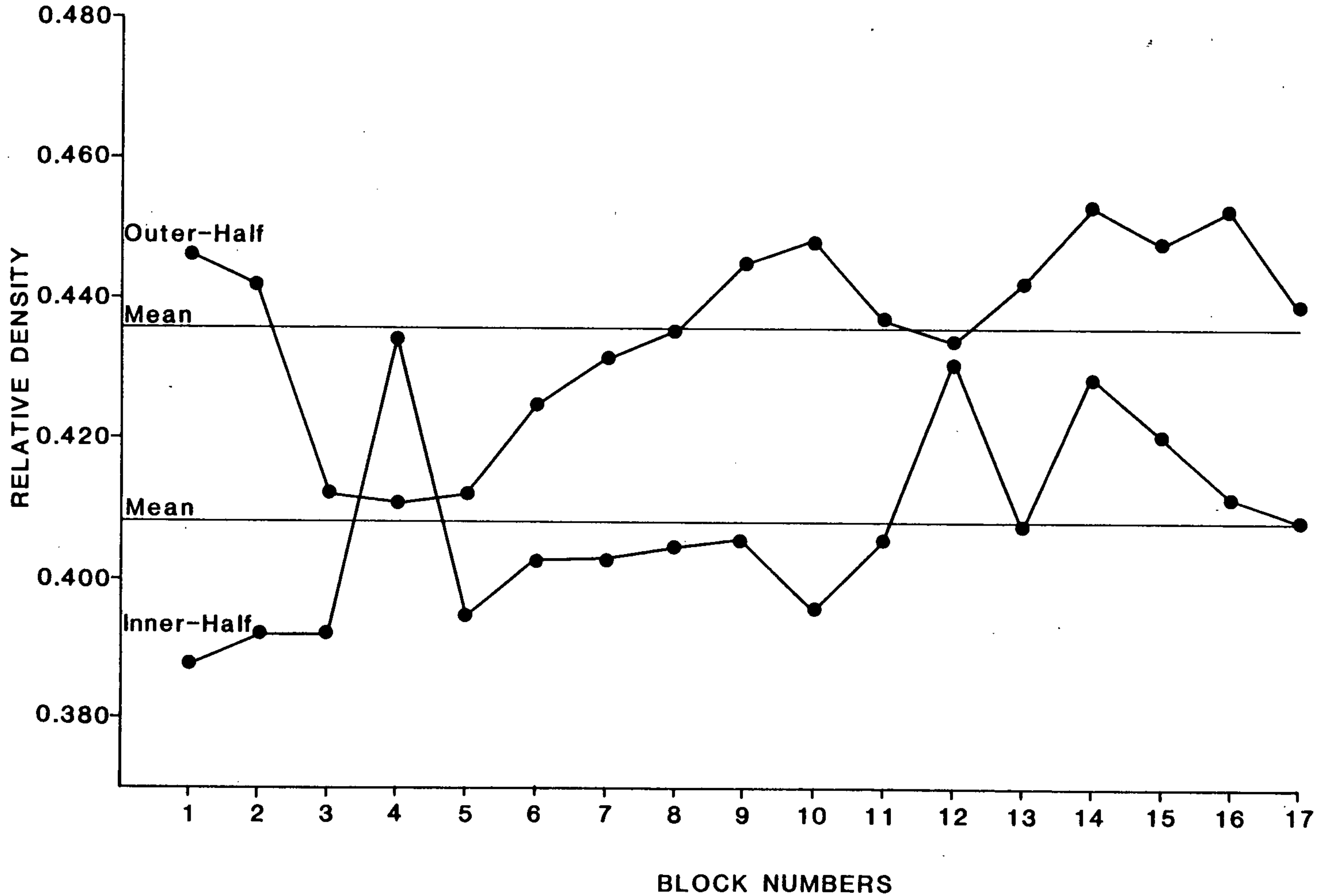

Figure 2. Variation in wood relative density at breast-height. (Disc 42-15)

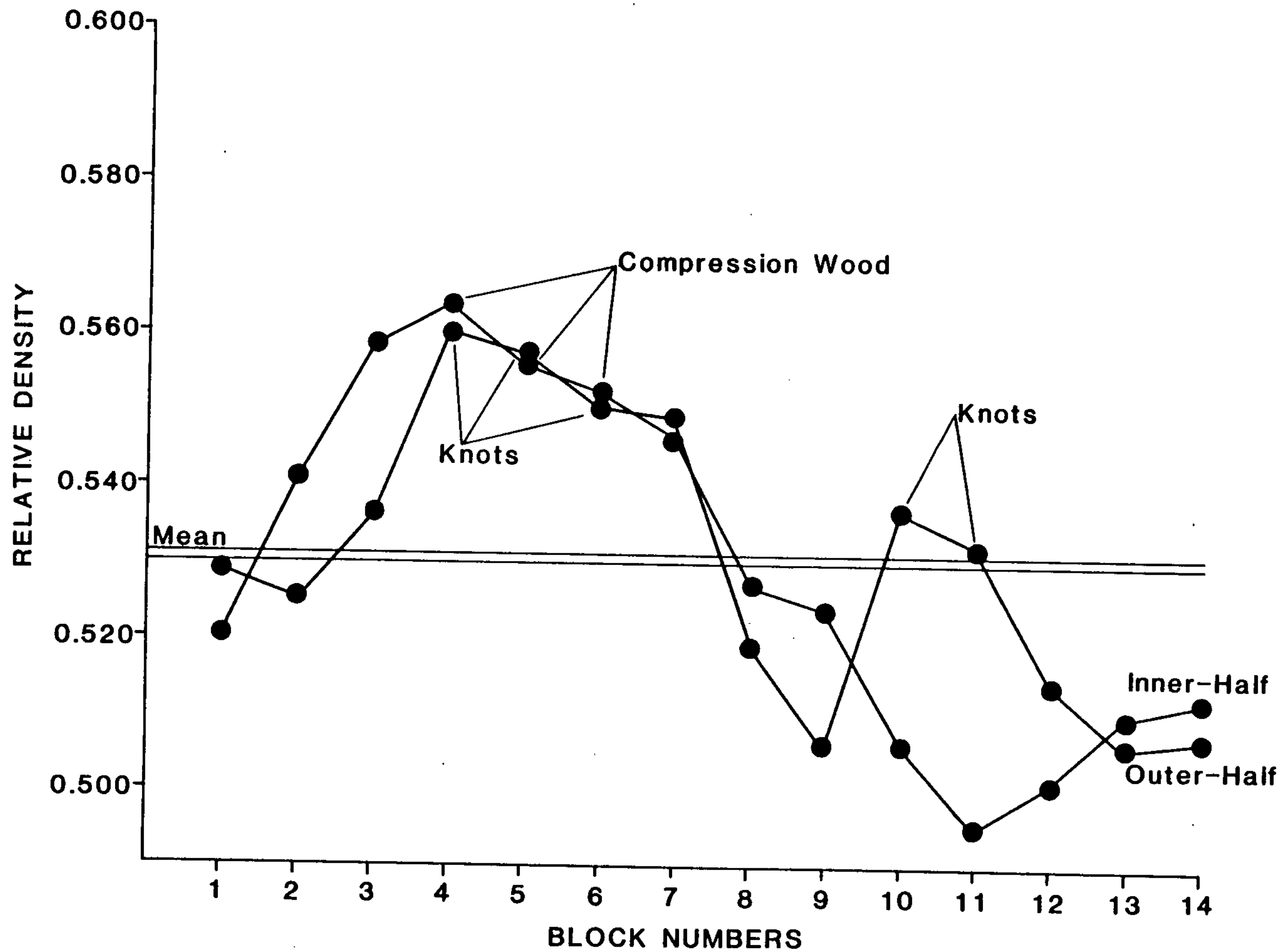

Figure 3. Variation in wood relative density at breast-height. (Disc 14-10)

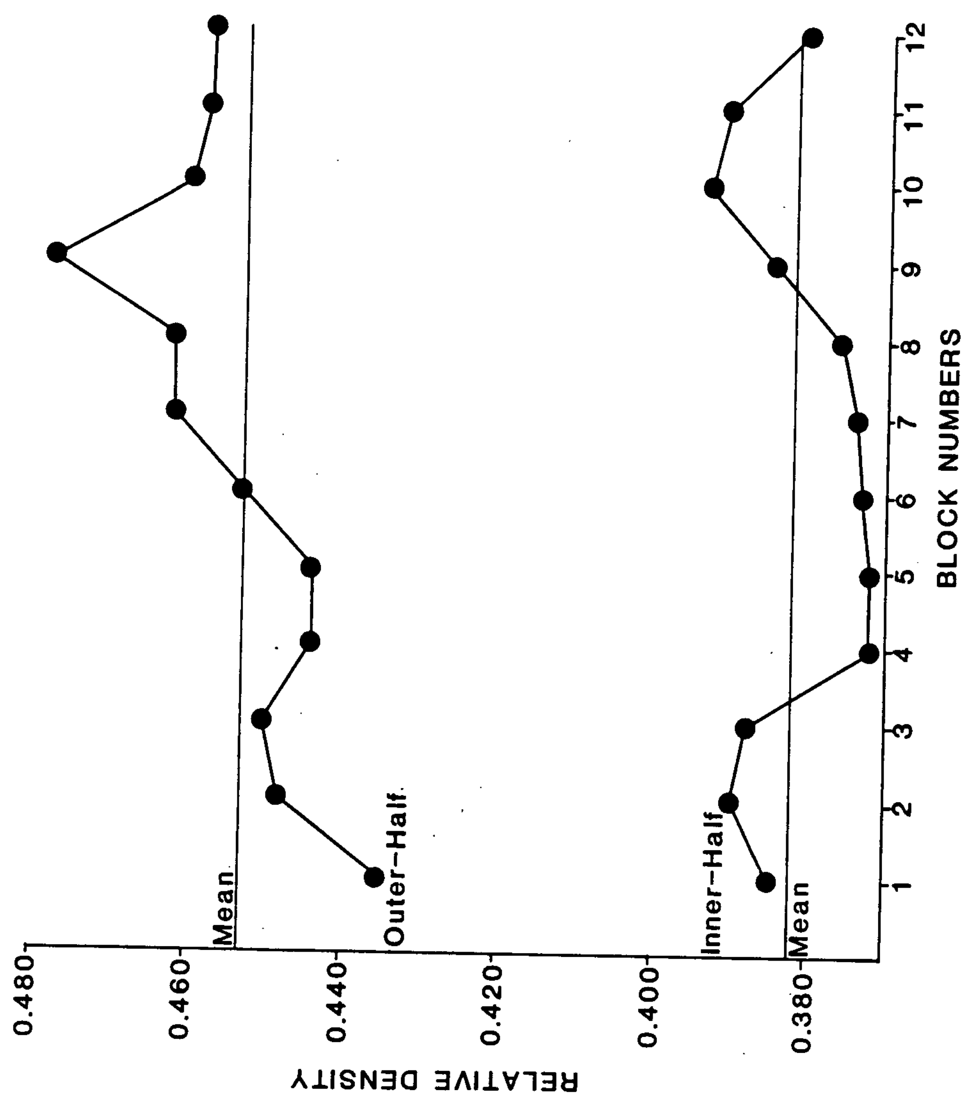

Figure 4. Variation in wood relative density at breast-height. (Disc 42-12)

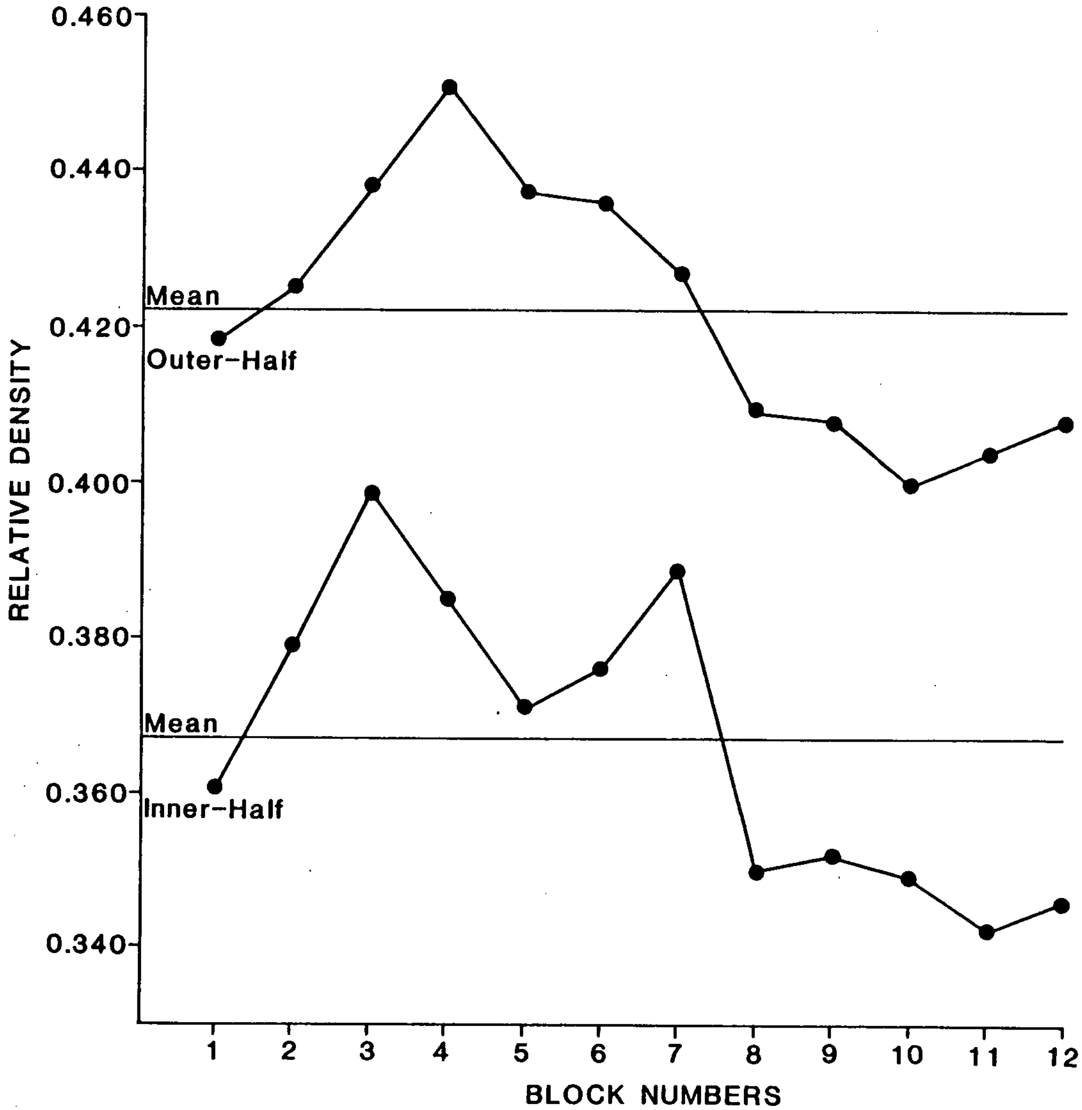

Figure 5. Variation in wood relative density at breast-height. (Disc 72-1)

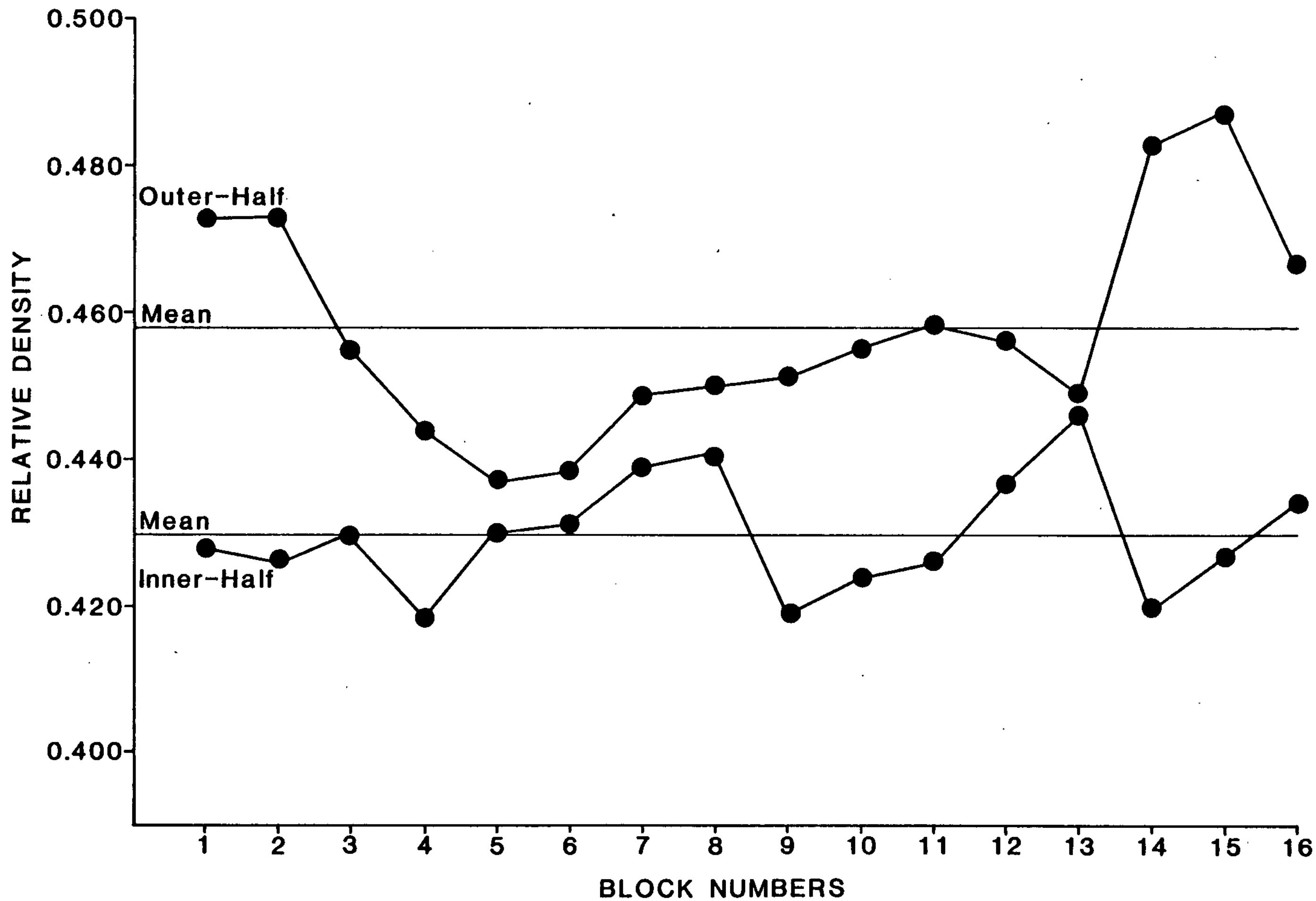

Figure 6. Variation in wood relative density at breast-height. (Disc 72-7)

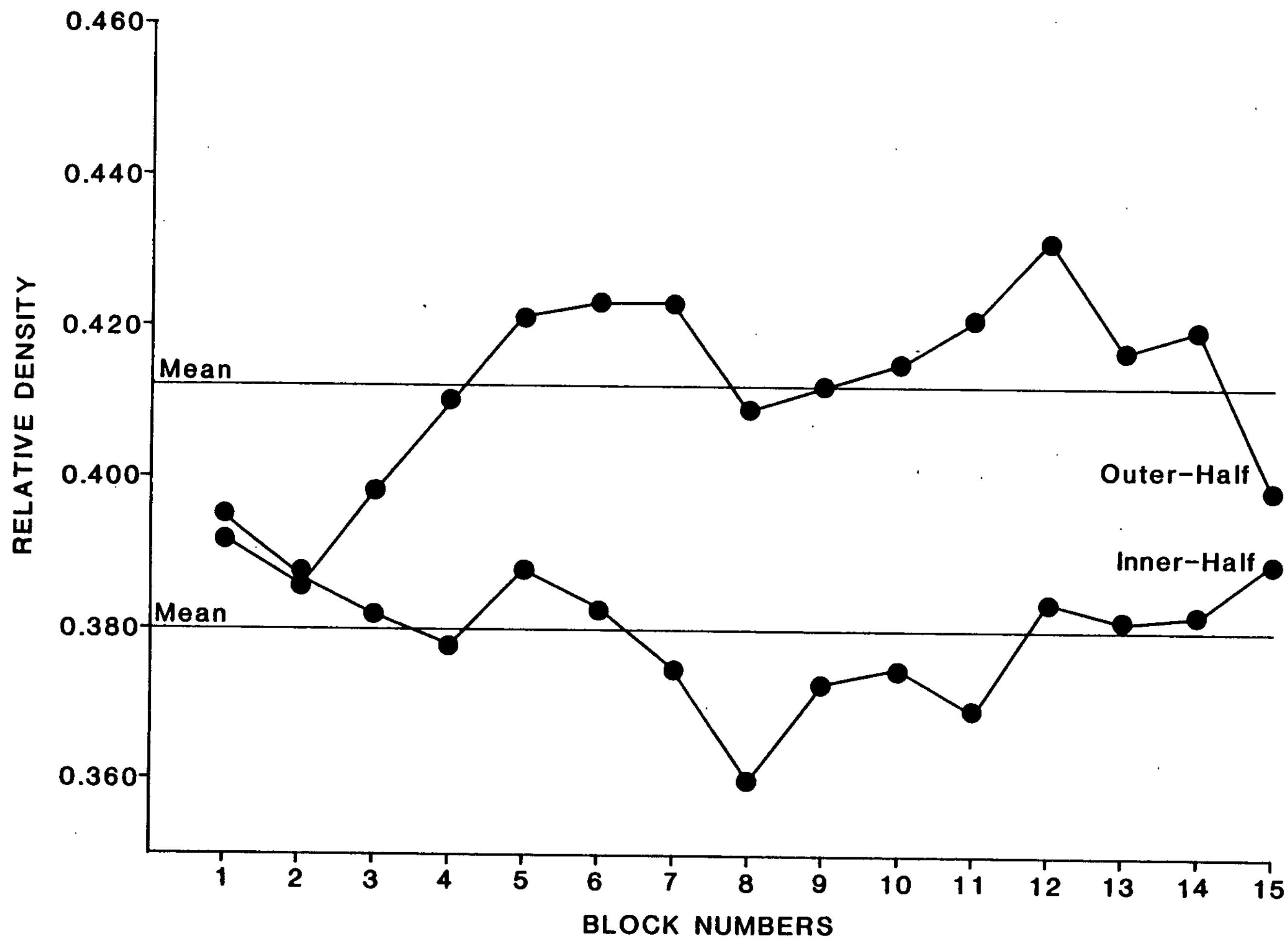

Figure 7. Variation in wood relative density at breast-height. (Disc 72-5)

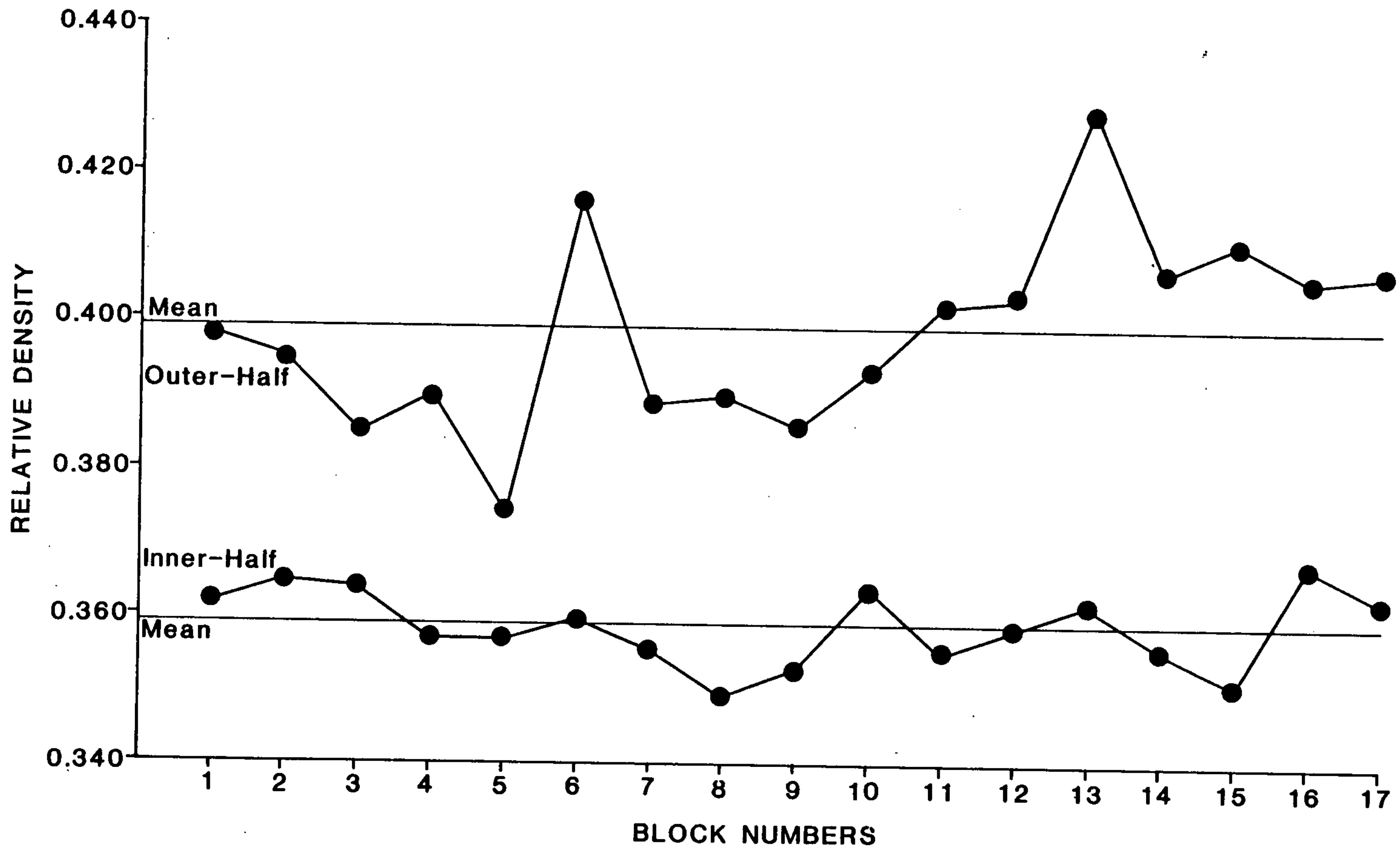

Figure 8. Variation in wood relative density at breast-height. (Disc42-10)

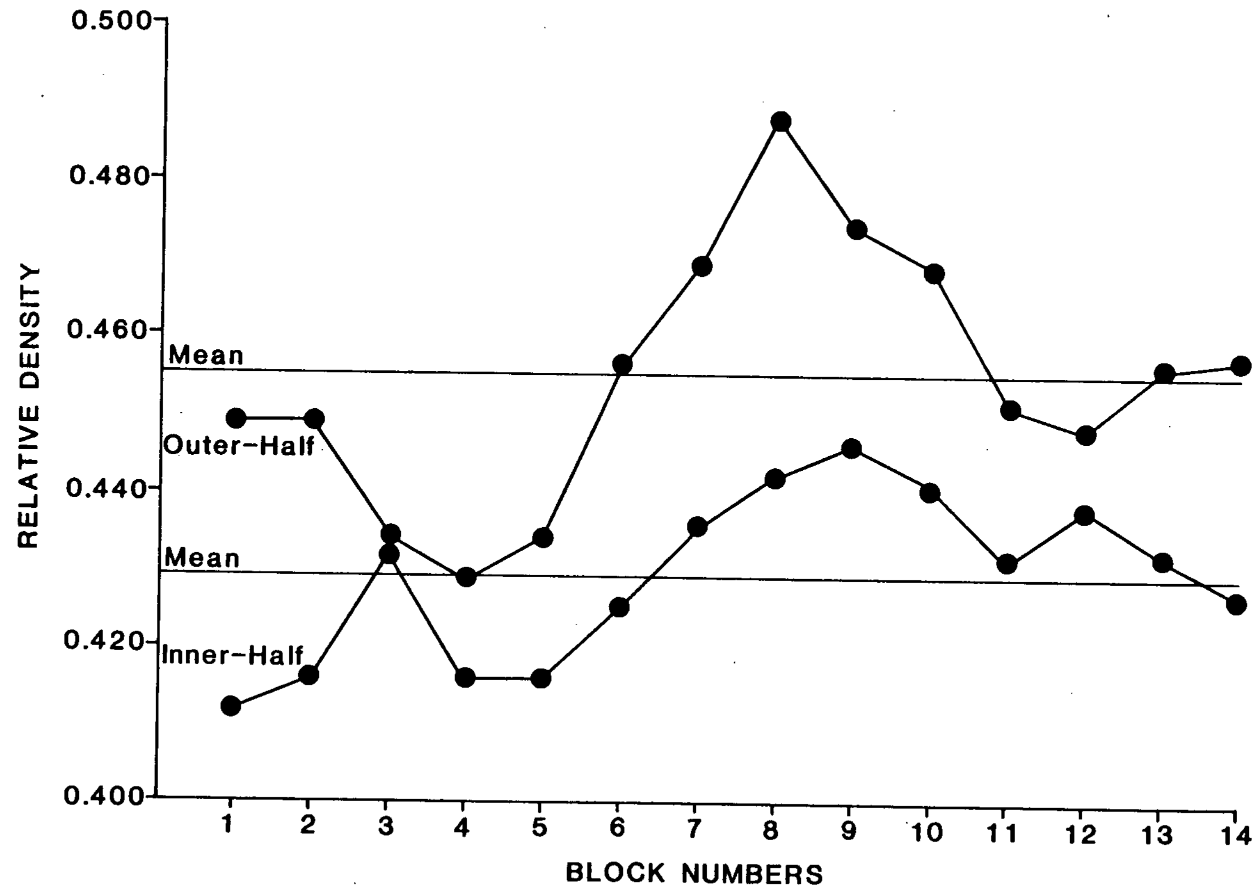

Figure 9. Variation in wood relative density at breast-height. (Disc 14-2)

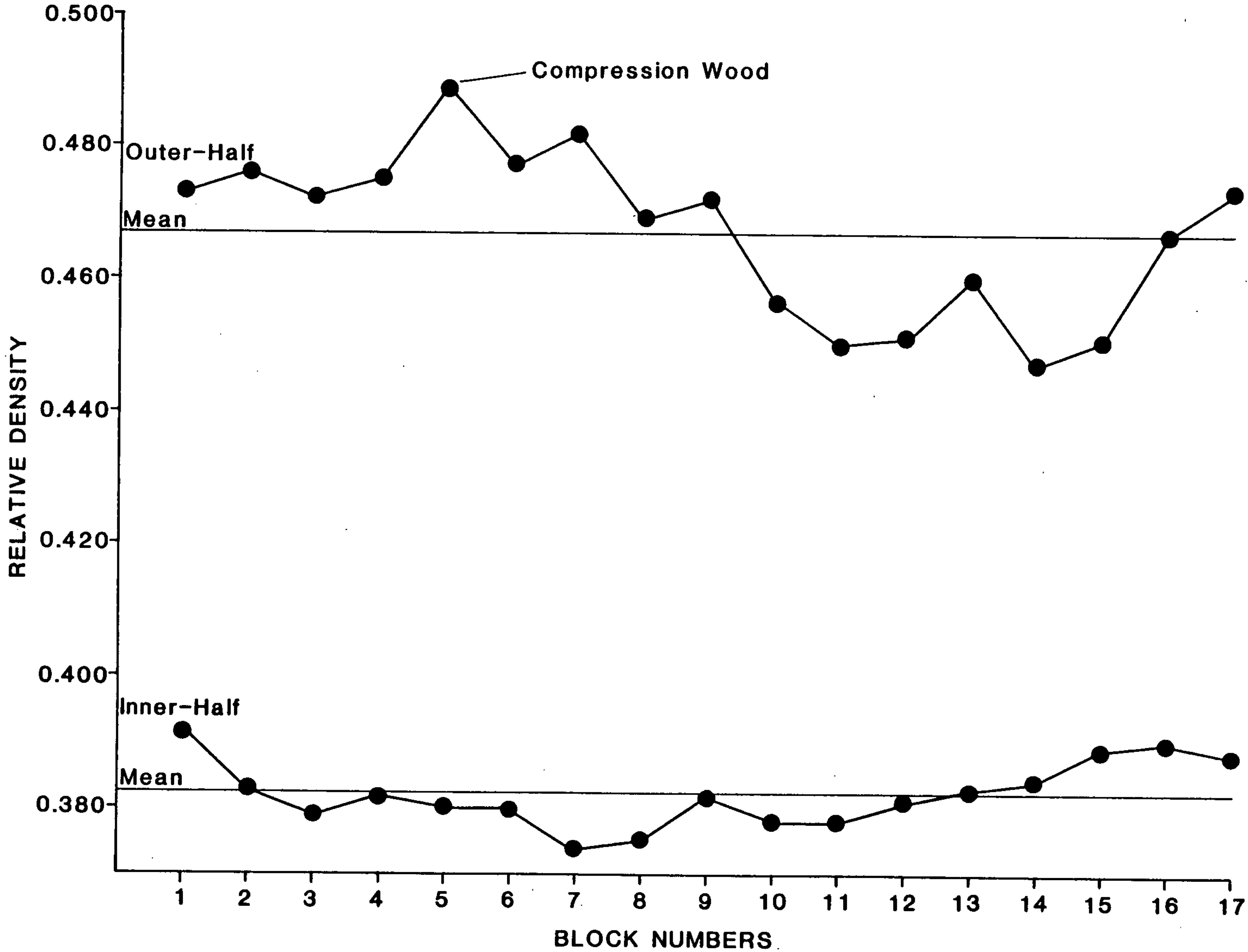

Figure 10. Variation in wood relative density at breast-height. (Disc 42-11)

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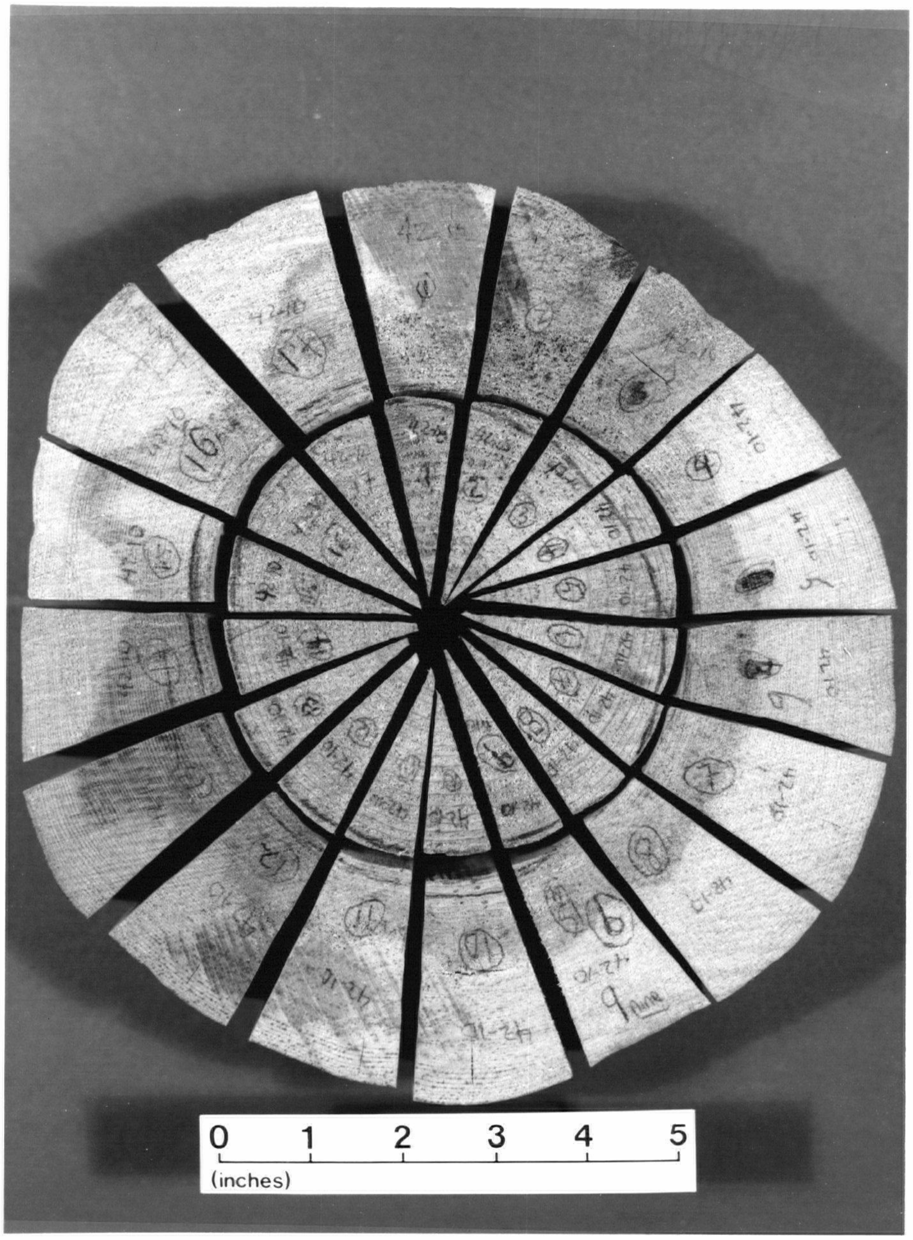

Figure 1. Breakdown of the discs.