UDK: 903.2:902.65(4-924.57)"633/634"
Documenta Praehistorica XXVII

Measuring Change: the Neolithic Pottery Sequence of Vinča-Belo Brdo

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ABSTRACT – *This paper examines the pottery sequence of the famous neolithic tell site of Vinča, Yugoslavia. In earlier research its stratigraphy of 9 m had been considered to be of only limited chronological value, since the excavator failed to document the position of finds in regard to actual layers, and recorded only the respective spit of the excavation. Theoretical considerations and a statistical analysis attempt to evaluate which chronological resolution can be achieved using the old find material. Recent radiocarbon dating of stratified samples from the old excavation is used to establish an absolute time scale for the stratigraphy. The stratigraphic information is used to reduce the statistical error of these dates caused by the calibration process. Finally, the quantitative change in pottery type frequencies is compared with the interpolated rate of sedimentation. This comparison makes it possible to distinguish between innovation or stagnation phases in the production of pottery and differences in the accumulation rate of settlement debris.*

IZVLEČEK – *V članku se ukvarjamo s keramiko iz znamenitega neolitskega tel najdišča Vinča v Jugoslaviji. V zgodnejših raziskavah so smatrali, da ima 9-metrska stratigrafija najdišča le omejeno kronološko vrednost, saj izkopovalci niso dokumentirali lege najdb glede na dejanske plasti, ampak so zapisovali le odgovarjajoče režnje. S teoretičnim razglabljanjem in statističnimi analizami poskušamo oceniti, kakšno kronološko ločljivost lahko dosežemo z najdbami starih izkopavanj. Z novejšo radiokarbonsko datacijo stratificiranih vzorcev iz starih izkopavanj smo izdelali absolutno časovno skalo stratigrafije. Stratigrafske podatke uporabljamo, da zmanjšamo statistično napako teh datacij, ki jih povzroča kalibracijski proces. In končno, kvantitativno spremembo v pogostosti tipa keramike primerjamo z interpolirano stopnjo sedimentacije. Ta primerjava omogoča ločevanje med inovativnimi in mirujočimi fazami v proizvodnji keramike ter med razlikami v stopnji akumulacije črepinj v naselbini.*

KEY WORDS – *Vinča; Neolithic; stratigraphy; seriation; radiocarbon dating*

THE SITE

The tell site of Vinča Belo Brdo near Belgrade (Yugoslavia) is among the best-known archaeological sites of south-eastern Europe. Not only has it become the type-site of the Vinča culture, with its approximately 9 metres of cultural deposit, it also scores among the longest stratigraphic sequences of the European Neolithic. Since the excavator, M. M. Vasić, published his four volume *Praistorijska Vinča* between 1932 and 1936 (*Vasić 1932; 1936a; 1936b; 1936c*), Vinča has remained not only a key point of reference for the research on Balkan Neolithic, but also an object of controversial debate. The publication of Vasić, while being well ahead of its time with regard to the thoroughness of the documentation and classification of finds, failed to describe with equivalent accuracy the structural remains uncovered during the excavation. The excavation method consisted in removing horizontal levels of 10 cm thickness and marking on most finds the vertical distance from an arbitrarily chosen zero point. However, none of the finds and only a few observed houses were recorded in their horizontal position. Thus subsequent research concentrated mainly on chronological and typological analyses of the find material (*Holste 1939; Milojčić 1943; 1949a; 1949b; Garašanin 1951; 1979*), whereas few studies attempted to reconstruct the position of structures and the sequence of building phases (*Korošec 1953; Jovanović 1960; 1984; Chapman 1981; Stalio 1984*).

By grouping the artificial levels of the type-site in intervals of 1–1.5 m, several phasing systems have been developed which were gradually regarded and used as being valid for the whole area of the Vinča culture. The two main chronological systems of M. Garašanin (*1951; 1979*) and V. Milojčić (*1949*) concur in their major stratigraphic divisions at ▼ 8.0, 6.0 and 4.1 m, while minor subdivisions are assumed at ▼ 7.5, 7.0 and/or 6.5 m respectively. The type spectrum in their periodisations comprises almost exclusively material published by M. Vasić (*Vasić 1932–36*), but neglects his personal selection of "relevant" types and artefact attributes for publication. The diagnostic types of Vinča culture in the Garašanin and Milojčić system thus appear as a rather arbitrary selection from the bulk of restored vessels from the type-site. For their selection, neither absolute frequency nor stratigraphic distribution are specified. Especially in a stratigraphic sequence of contested reliability, as in Vinča-Belo Brdo, conclusions based on single occurrences of types and elements may be quite misleading if their overall distributional characteristics have not been analysed beforehand.

A systematic quantitative study of pottery types and elements in their stratigraphic distribution thus appeared a promising approach for reassessing the chronological validity of the Vinča sequence. On more general methodological grounds the aim was to test which chronological "resolution" can be achieved in a stratigraphic analysis restricted to given 10 cm-levels without reference to the real sedimentation and construction layers.

REAL AND ARTIFICIAL STRATIGRAPHY

A model was developed to analyse theoretically the distorting effects of a find recording system in regular vertical steps superposed on a realistic settlement stratigraphy (Figs. 1a, 1b). The unknown percentage of material that differs in age from the bulk of finds in each 10 cm-level is defined in the present study as "stratigraphic contamination". Theoretically, we can distinguish two types of contamination: the first is caused by the unintentional overlapping of adjoining layers (Fig. 1b: A, B), the second by intrusions of far later (unrecognised deep pits) or far older artefacts, which result, for example, from finds in sediment re-used as building material (Fig. 1b: pit from layer 2 in level C). Obviously, the remaining chrono-

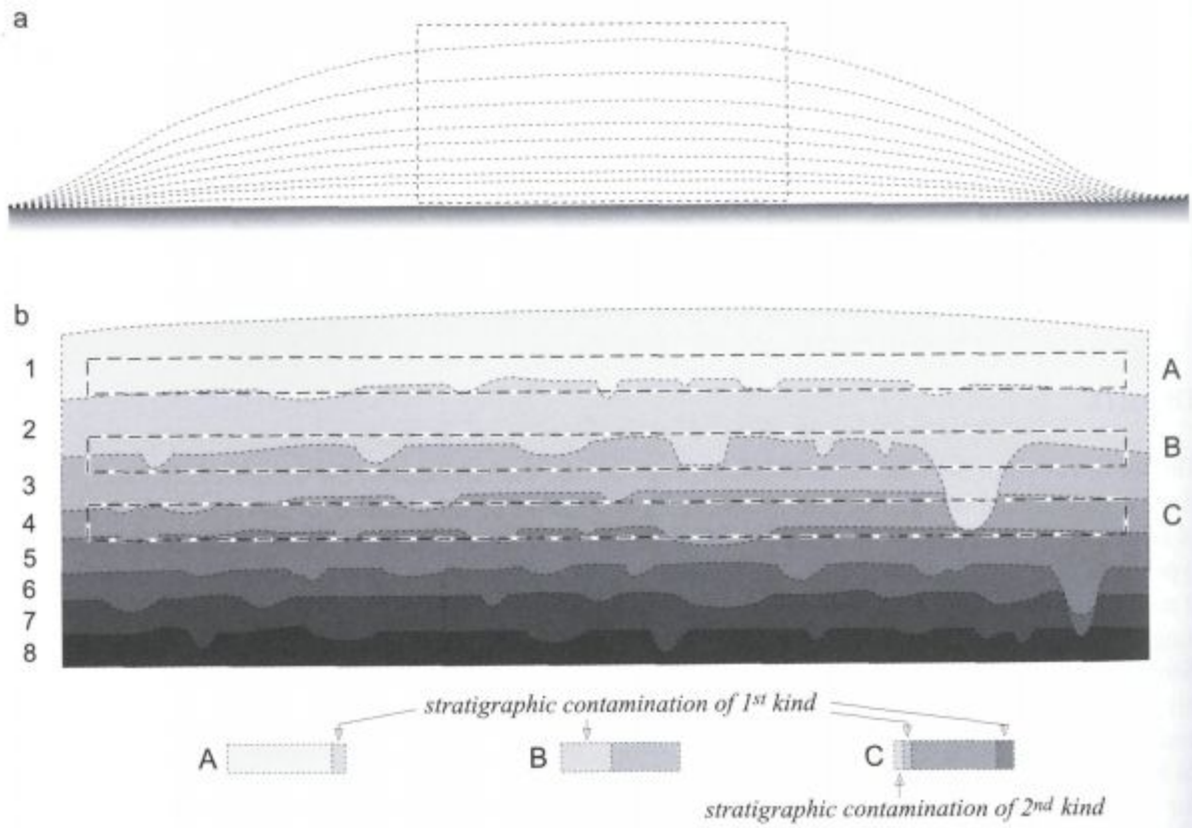

Fig. 1. Idealised tell stratigraphy (a) and enlarged section (b), showing possible superposition of layers and excavation units.

logical value of a contaminated stratigraphy depends on both kind and quantity of contamination. Figure 2 illustrates the likely effects of stratigraphic contamination on an idealised vertical distribution pattern of diagnostic types. Contaminations of the first kind will result in a flattening or shifting of unimodal distributions of the types concerned (Fig. 2b). A certain amount of intrusive sherds (contamination of the 2nd kind, Fig. 2c) will show up as a bimodal or even polymodal stratigraphic distribution of some types. Beyond a certain critical threshold contaminations of both degrees will distort the unimodal type distribution patterns up to a total loss of stratigraphic information – the state of *chronological entropy*. Inversely, a pattern of overlapping unimodal type distributions will only be detected in a given stratigraphy when there is comparatively little contamination.

STATISTICAL ANALYSIS OF STRATIGRAPHIC UNITS

Since the same model of overlapping unimodal frequencies is the methodological basis of seriation techniques, our approach applies seriation as a tool for testing the stratigraphy of Vinča-Belo Brdo. However, unlike its usual applications, seriation is used here in reverse: instead of chronologically ordering a number of closed find units, we examine the chronological "closedness" of a number of find complexes, the sequence of which is predetermined stratigraphically. The seriation technique chosen is correspondence analysis (CA), a powerful statistical tool (*Greenacre 1989; Madsen 1988; Djindjian 1991.181–186*) sensitive in the detection of distorting factors in a generally seriable data matrix.

Before being submitted to seriation, however, the pottery sample of Vinča-Belo Brdo required reclassification and further statistical pre-treatment. A sample of about 3400 pottery fragments served for a new classification of vessel shapes, decoration and handle types. Among the most numerous vessel category of bowls, amounting to 80 % of all fragments, 180 types could be distinguished, organized into 23 type groups. It is well known that archaeological types are artificial groupings not (necessarily) corresponding to functional or aesthetic classes in the potter's mind. Such a highly differentiated classification system, as developed here, intends to resolve a morphological continuum in the smallest discrete entities attainable in order to reproduce quantitatively the time scale in terms of pottery change. However, a classification should allow for an average type frequency that is still statistically meaningful. The types of pottery shape which are used in this study show a minimum frequency of 5 and an aver-

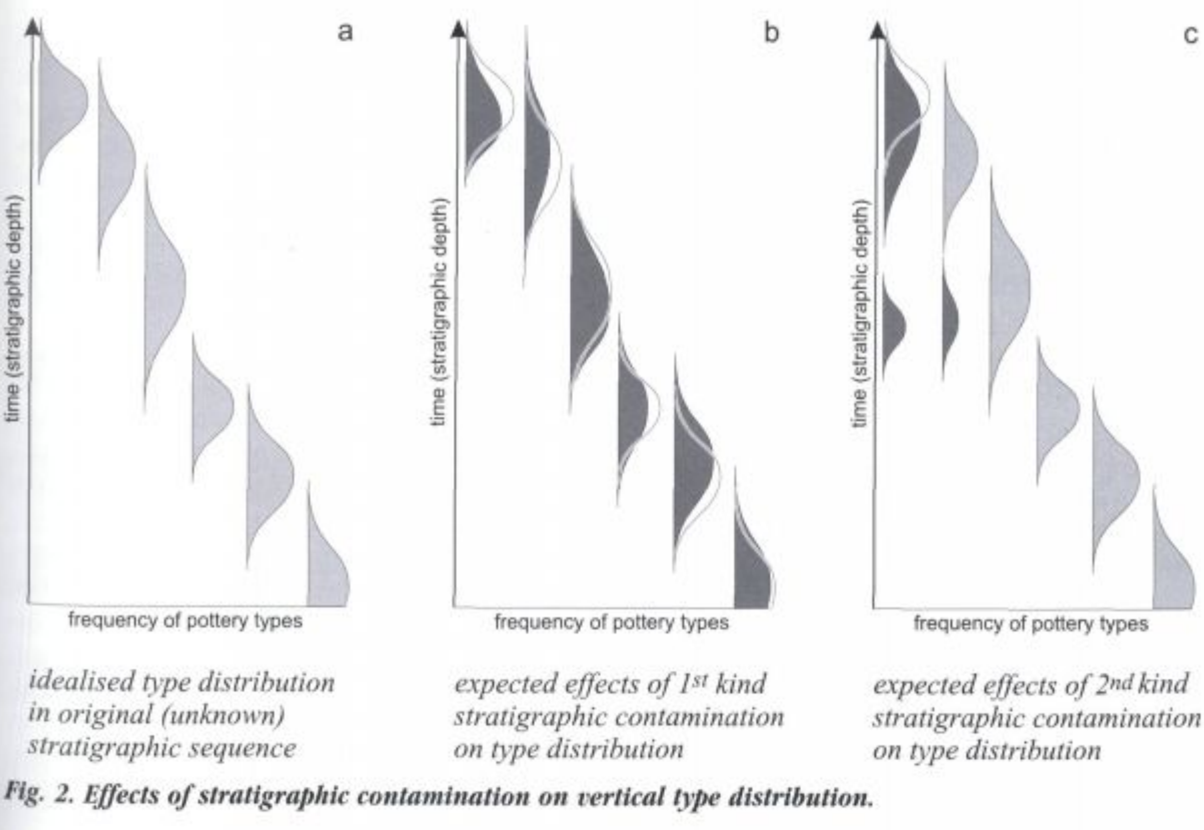

Fig. 2. *Effects of stratigraphic contamination on vertical type distribution.*

age of 10, with many of the chronologically most significant types exceeding 20 occurrences.

A sub-sample of 950 vessel fragments was subjected to a metric analysis: the coordinates of crucial profile points and the length, angle and curvature of the intermediate profile sections were recorded. On the basis of these measurements and derived proportions a number of cluster, variance and discriminant analyses were performed to verify the visual classification of the whole sample. Vessel decoration was classified, separating its components into (1) decorative technique, (2) decorative motif/pattern, (3) composition of one or several decorations (in zones, repetitive, alternating, limiting) and (4) position of the decoration on the vessel (rim, shoulder, lower part, interior). All four components could be shown to vary throughout the stratigraphic sequence, i.e. to have some chronological value.

As a further step, the analysis of stratigraphic frequency distribution provided information for the assessment of the chronological significance of shape types and decorative elements. Obviously, not every type or variant of vessel shape or decoration can be expected to show significant chronological variability. Many formal or technical details of pottery production may vary for functional or simply individual reasons. Even in a schematic stratigraphy, as in Vinča, the vertical distribution of types and elements can be regarded as a coarse indication of their variability in time. In order to minimize the effects of stratigraphic contamination types with obvious bi- or polymodal distribution were excluded. Only those shape types were included in the CA, whose interquartile range (central part of stratigraphic distribution without lowermost and uppermost 25% of occurences) did not exceed 1.4 m, a value that was chosen on the basis of dispersion diagrams. A similar selection was performed on decorative motifs and techniques, where only few types passed the interquartile criterion. In general, morphological variability of Vinča pottery proved to be a far better indicator of time than decorative variability.

The seriation of a stratigraphic sequence can be visualised as the attempt to sort a number of find boxes (each containing the material of a single stratification unit) whose identification labels have been lost. Such an experiment can only be successful if (a) the stratigraphy encompasses sufficient time to allow for substantial change in artefact types, (b) the type classification is detailed enough to reveal slight and gradual change, (c) the sample size is sufficient to enable differences in the type percentages to attain statistical significance, (d) the chronological variation *in* the given units is considerably smaller than *between* them. In other words, they should show a sufficient degree of chronological homogeneity.

The seriation matrix used in the present study measured the relative frequency of 204 pottery types and decorative elements in 39 stratigraphic units. These units comprise pottery samples of the excavated 10 cm levels from ▽ 9.3 to 5.0 m, some of which in our analysis had to be paired or grouped to compensate for the small sample sizes. A number of pits discovered in the lowermost horizon at Vinča were also included, which rather traditionally than convincingly have been interpreted as semi-subterranean dwellings (*Korošec 1953.40; Stalio 1984.34–36*). Figure 3 shows the relative frequency of shape and decoration types in the stratigraphic units as ordered by the first *eigenvector* of correspondence analysis. Not only is a general pattern of shifting stratigraphical distributions obvious, but there are also differences in their specific range. Decoration techniques or motifs (M..., DT...) have much longer lifespans than pottery shapes (S..., A.., F.., K.., T..). While the central part of the frequency distribution is well ordered in a diagonal way, some extremely early or late isolated occurrences suggest a certain amount of stratigraphic contamination of second degree.

Figure 4 represents the distribution of unit scores in the plane of the first two *eigenvectors* of CA. The diagram shows a fairly symmetrical arrangement of the units in the shape of a parabola, a statistical indication of a data matrix that can be diagonalised very well (*Greenacre 1989.226–231*). Obviously, a pattern of overlapping unimodal type frequency distributions can be discovered in the sequence of 10 cm levels at Vinča.

Looking more closely we see that the seriation sequence starts in the lower left corner with pit Z (an almost pure complex of the preceding Starčevo culture), followed by a group of other pit contents. Very closely clustered are the lowermost levels above the sterile loess subsoil from ▽ 9.3 to ▽ 9.0 m. Projected on the first *eigenvector* which we interpret as time scale there is almost no chronological difference. Separated by a gap, the pits W, M and K are grouped around the (reversed) levels ▽ 8.9 and ▽ 8.7 m. After another interruption the levels from ▽ 8.5 to ▽ 8.0 m appear in perfect stratigraphic order, while the levels from ▽ 7.8 to ▽ 7.1 m cluster in two

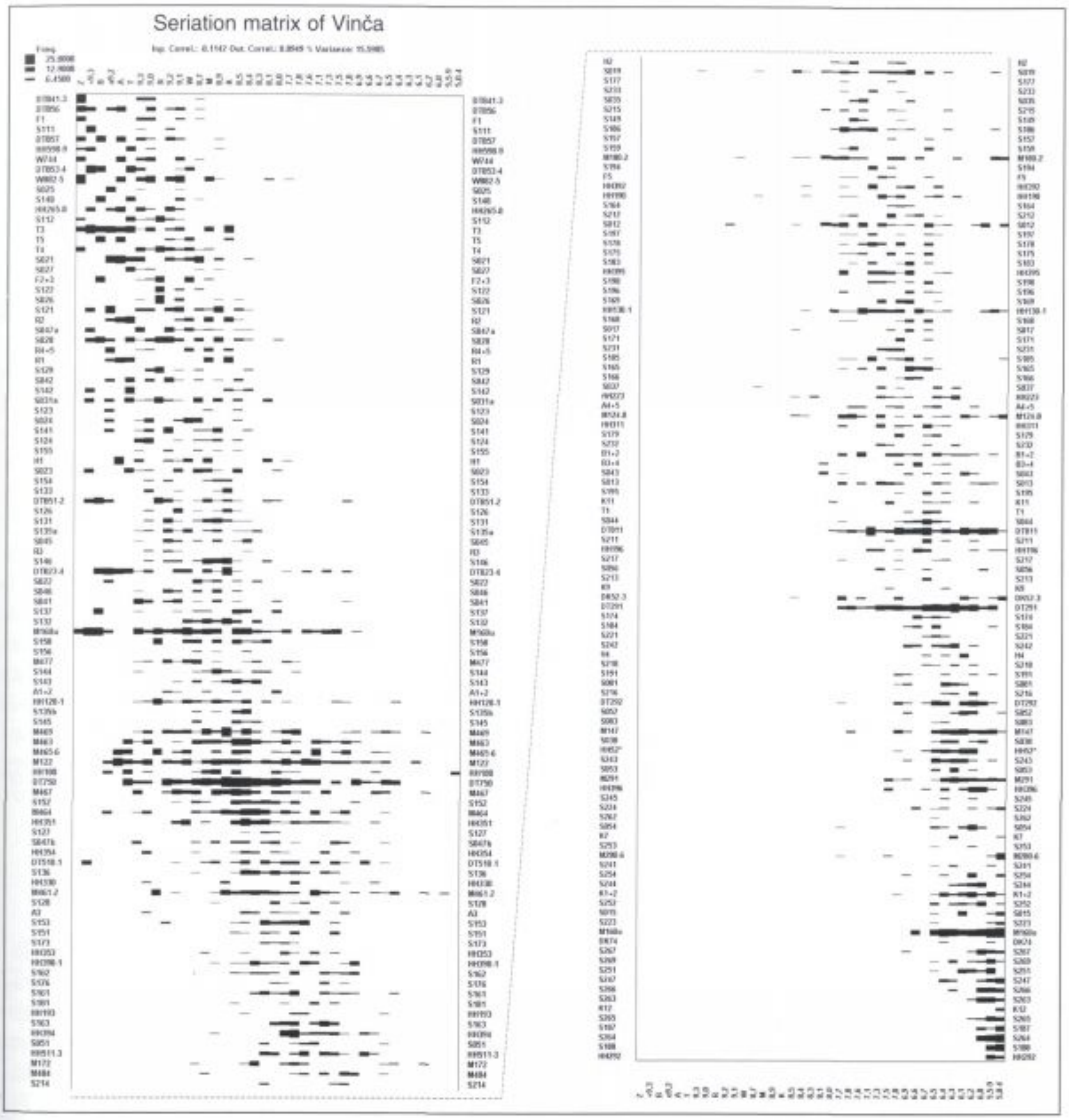

Fig. 3. Abundance matrix of pottery types and attributes in stratigraphic units, seriated by Correspondence Analysis.

groups rather than in stratigraphic sequence. From ▿ 7.1 m up to ▿ 5.0 m the stratigraphic units are once again arranged by CA in correct order, with the exception of level ▿ 6.2, being slightly misplaced. Apart from the levels between ▿ 7.8 and ▿ 7.1 m, which will be discussed below, the given stratigraphic sequence of Vinča Belo Brdo can thus be reproduced statistically on the basis of type combinations only. Furthermore, the ability of CA to space data points in a two-dimensional plane according to their similarity/dissimilarity allows borderlines between cultural phases to be defined empirically rather than to be drawn arbitrarily. Thus we can distinguish phases 1 to 7 in Vinča with a threefold subdivision of phase 5 (a, b, c) and a possible subdivision of phase 2 (Fig. 4). These supposed phase boundaries derived from gaps in the eigenvector plot were subjected to further statistical testing. A one-way analysis of variance confirmed that there are significant differences in type frequency between all of the phases except 2a and 2b. These two sub-phases, however, could be separated by a discriminant analysis, which reproduced the given groups (stratigraphic units combined to phases) perfectly (100% correctly classified), using three canonical functions calculated from type frequencies,

Since stratigraphy and type seriation represent functions of real time, we may compare them in a cor-

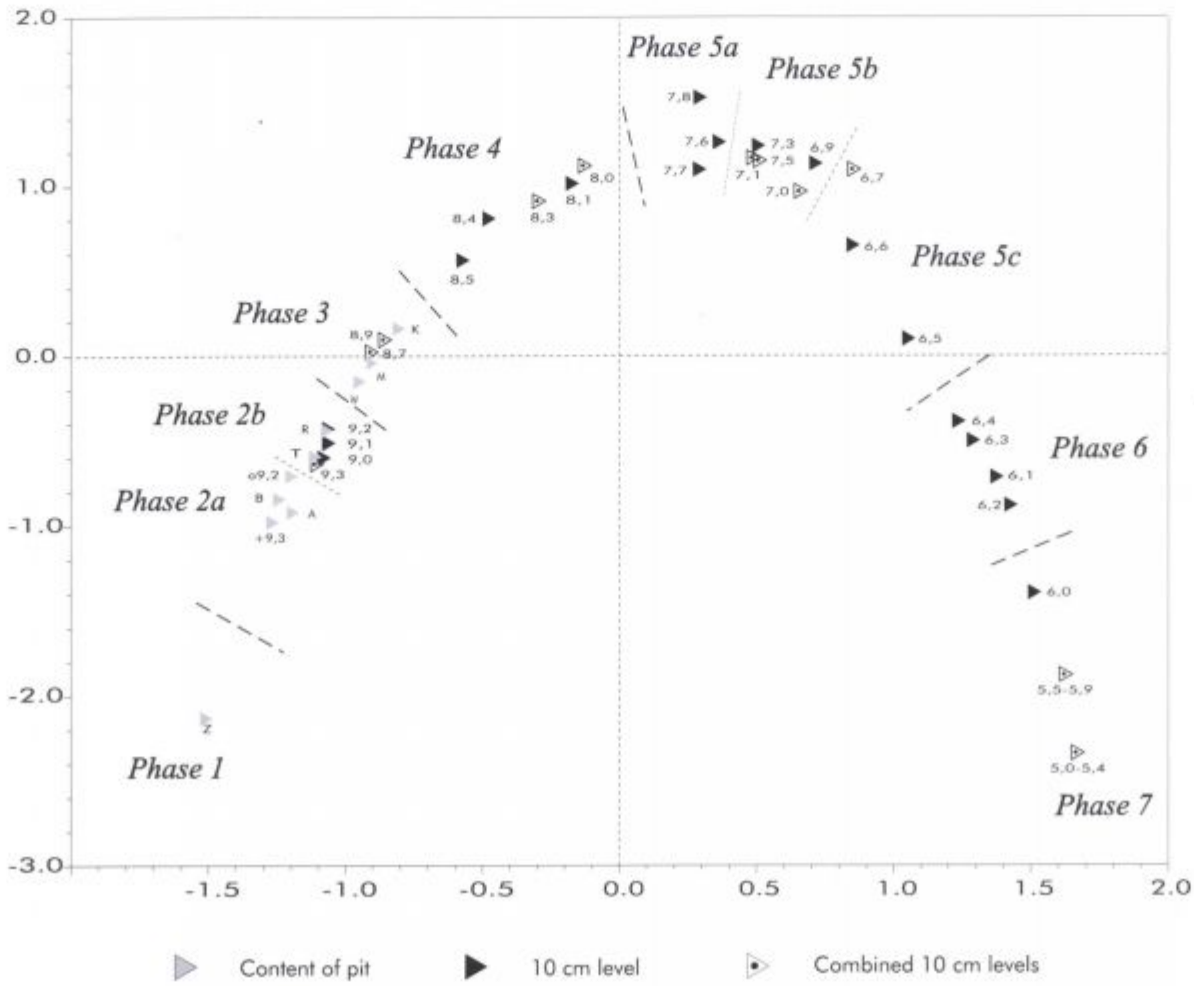

Fig. 4. Stratigraphic units in the plane of the first two eigenvectors of CA.

relation diagram (Fig. 5). A polynomial regression curve was calculated which suggests a very high non-linear correlation (r = 0.99) between stratigraphic position and similarity in type composition expressed by the first eigenvector of CA. Especially interesting are the residuals, i.e. the points lying at a greater distance from the regression curve. In the lower left corner of Figure 5, three groups of pits (shaded triangles) are discernible: the pits at ▼ 9.3 and ▼ 9.2 m as well as A and B according to their type composition appear earlier than their stratigraphic position would suggest. The pits W, M and K, despite being discovered at almost the same depth, contain considerably later types. An intermediate position is assigned by the first eigenvector to pits T and R.

Statistical analysis thus suggests that the pits in the lowest level of Vinča-Belo Brdo do not form a chronologically homogenous "pit horizon" as was assumed hitherto. Instead, several pits were probably dug from different levels (accordingly with different fill), which the excavator presumably recognised only when the lighter sterile loess subsoil had been reached (between ▼ 9.0 and ▼ 9.4 m). The correlation diagram also shows several adjoining stratigraphic units which are indistinguishable on the basis of their type contents and therefore deviate from the regression curve: the levels of ▼ 9.2-9.0 m, ▼ 7.8-7.7 m, ▼ 7.5- 7.1 m and ▼ 6.8-6.6 m in Figure 5 appear piled up, instead of being spread along the regression curve.

Several conclusions can be drawn from these results. Firstly, the chronological resolution of Vasić's schematic, 10 cm levels is far clearer than generally assumed; in large patches of the stratigraphy even a difference in depth of only 10 cm is chronologically meaningful. Secondly, the contamination effects caused by unrecognised pits and/or the crosscutting of sedimentation layers which do not run horizontally (cf. Fig 1b) cannot be considered serious enough to discredit the whole stratigraphic sequence. Thirdly, when based on CA and statistically tested, the grouping of stratigraphic units into phases can be regarded as methodologically sound.

CULTURAL DYNAMICS AND THE GROWTH OF TELL SETTLEMENTS

Chronological blocks based on a combination of stratigraphy and typology can thus be resolved into a pattern of gradually shifting type composition by seriating the artificial stratigraphic units. Since correspondence analysis can not only sort find complexes on an ordinal scale, but reproduces geometrically in few dimensions the overall (dis)similarity pattern of the units (and types), we can attempt to analyse a problem which is crucial to many archaeological find sequences: the problem of cultural dynamics. The refined chronological resolution enables a quantification of the change in find composition between adjoining units on a stratigraphic scale. This stratigraphic scale, however, is proportional to the real time scale only if we have evidence to assume an uninterrupted continuous accumulation of settlement debris at a constant rate. Unless tell accumulation can be shown to be a linear function of time, differential change between adjoining stratigraphic units can always be interpreted in an ambiguous way: Greater dissimilarity can be caused by cultural innovation, or by lower accumulation rate. Inversely, greater similarity in the type composition of two layers can result from cultural stagnation or from increased accumulation of sediment. The only way to resolve this ambiguity is to establish an independent time scale by means of absolute dating.

In contrast to its central importance for relative chronology, until now the type site contributed very little to the absolute dating of Vinča culture (*Breunig 1987.107; Todorović and Cermanović 1961. 101–102*). In 1991, a number of unworked bone and antler finds with documented stratigraphic positions were subjected to radiocarbon analysis. A promising, mathematically sophisticated approach has recently been published as an attempt to reduce the additional statistical error caused by the calibration process (*Buck et al. 1991; Buck, Litton, Smith 1992*). Bayesian probability theory is used to incorporate archaeological information in the calibration procedure. An application of this calibration approach, using the program OXCAL (*Ramsey 1994*), appears in Figure 6, in which 13 radiocarbon dates are arranged in reverse stratigraphic order. The open areas signify the probability distributions of all samples calibrated independently. The comparatively broad spread of their estimated ages results not from the measurement procedure itself, but from marked wiggles in the calibration curve between 5300 and 5000 cal BC. The application of *a posteriori* probabilities means

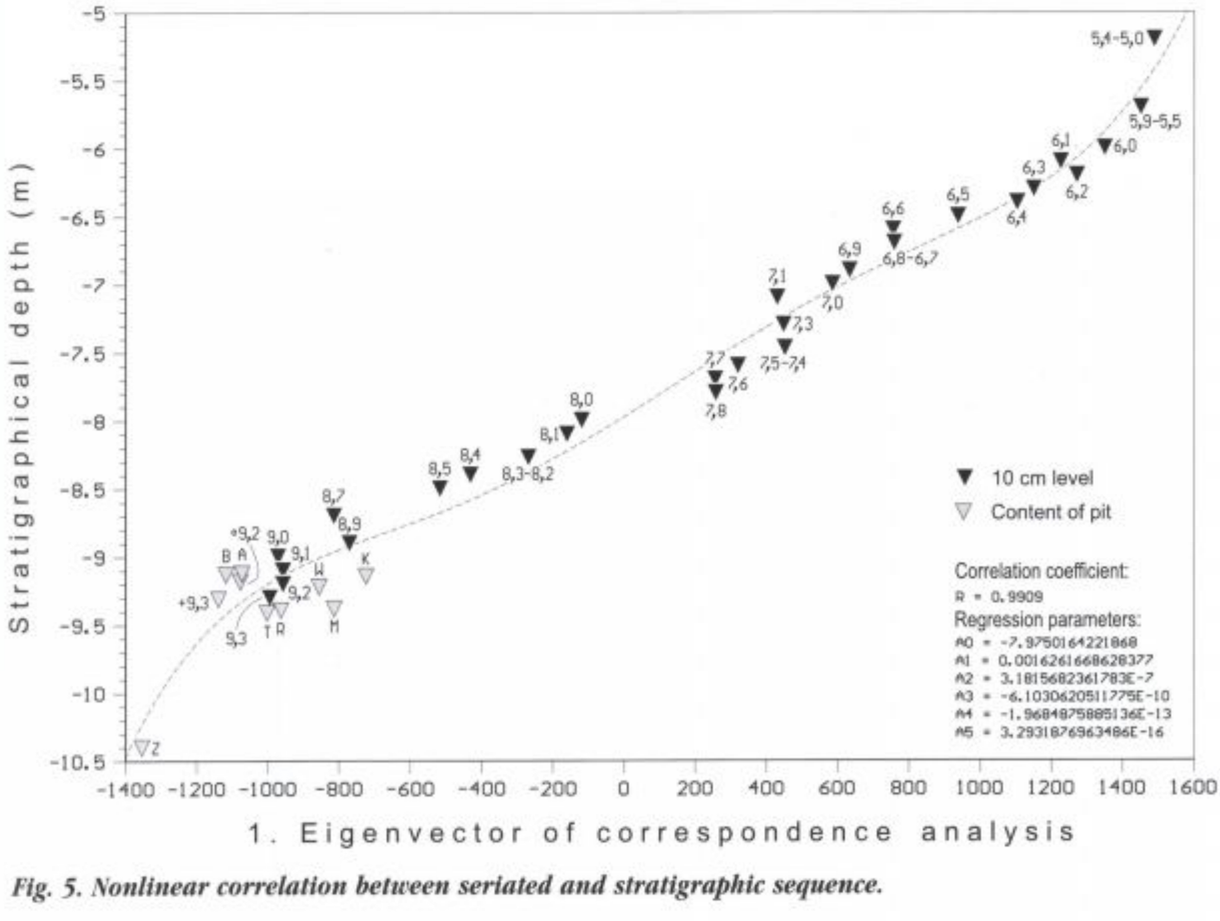

Fig. 5. Nonlinear correlation between seriated and stratigraphic sequence.

the use of stratigraphic evidence in order to exclude mutually overlapping parts of the respective probability distributions. We know, for example, that there should be a considerable difference in age between the samples from levels ▽ 8.7 and ▽ 7.0, which is not obvious from the calibrated radiocarbon dates. When their stratigraphic succession is taken into account, the posterior probabilities of calibrated dates (the solid areas in Figure 6) are much narrower than if calibrated independently.

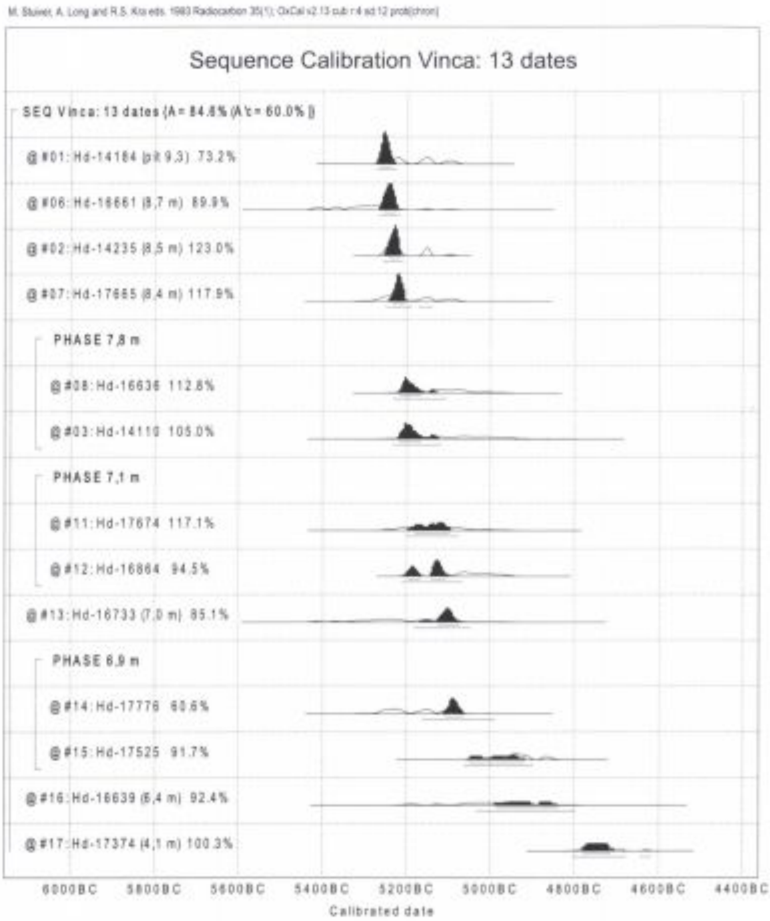

Fig. 6. Sequence calibration of 13 radiocarbon dates from Vinča.

Combining calibration with archaeological context information also means that the selection or rejection of samples becomes a crucial factor. Three of the 13 displayed radiocarbon dates in Figure 6 show a considerable deviation from the general trend; the sample Hd-14184 (pit at ▽ 9.3 m) appears too young, while the samples Hd-16733 (▽ 7.0 m) and Hd-17776 (▽ 6.9 m) produce excessively old age estimates. A tentative exclusion of these three dates leads to a somewhat different appearance in the remaining samples when calibrated sequentially (Fig. 7). The oldest date (▽ 8.7 m) now shows a much broader probability range (5415–5215 cal BC at the 95% level), which has shifted towards the older (left) part of the diagram. The general trend appears less steep than in Figure 6 and more s-shaped. Depending on the data subset and calibration approach used, we can estimate the maximum absolute time span for phase 3 to 6 (Vinča A2–B2) from either 5400 or 5250 to around 4850 cal BC. Unfortunately, two stratigraphically older samples could not be dated, and sample Hd-14184 from the pit at ▽ 9.3 m remains doubtful, as it yielded an even younger age than levels ▽ 8.5 and ▽ 8.4. So the beginning of Vinča culture at the type-site is still difficult to express in absolute dates.

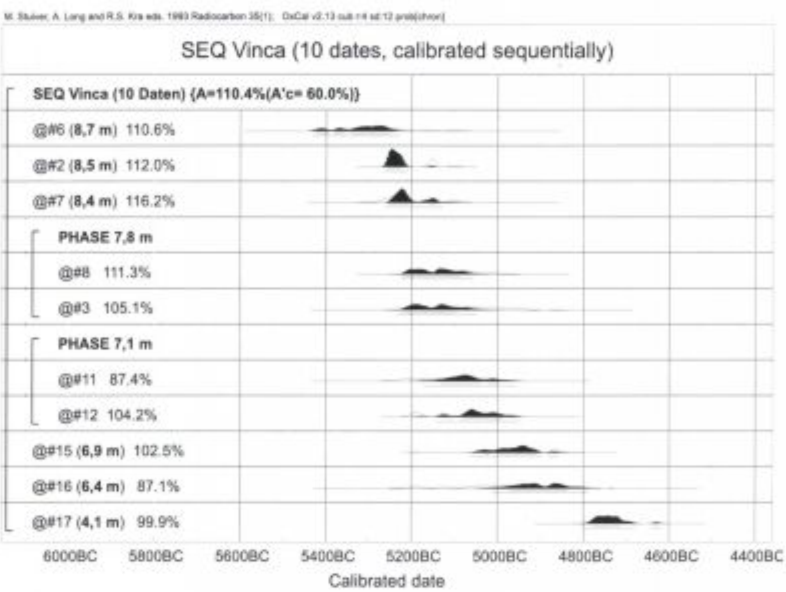

Fig. 7. Sequence calibration of 10 radiocarbon dates from Vinča.

Both radiocarbon data subsets are fairly small for assessing the absolute time scale of the settlement growth with sufficient accuracy. Nevertheless, a tentative correlation of the rate of both sediment accumulation and typological change with stratigraphic depth is proposed in Figure 8. The differences of the calibrated upper and lower 68 percent ranges of stratigraphically neighbouring dates were averaged, and then their vertical distance was divided by the mean time difference. A coarse extrapolation of the sediment accumulation rate can thus be achieved. The two data subsets only differ considerably below ▼ 7.1 m, where the exclusion of two unrepresentatively old dates reduces the accumulation rate by almost 50 percent. Below ▼ 8.5 m, the decision to accept or reject the radiocarbon date from the early pit at ▼ 9.3 m means to assume an either very slow (solid line) or extremely rapid (broken line) sedimentation process. The subset comprising 10 stratigraphically coherent dates shows a more balanced general trend of increasing sedimentation rate with time, a tendency that is markedly interrupted between ▼ 7.1 and ▼ 6.4 m.

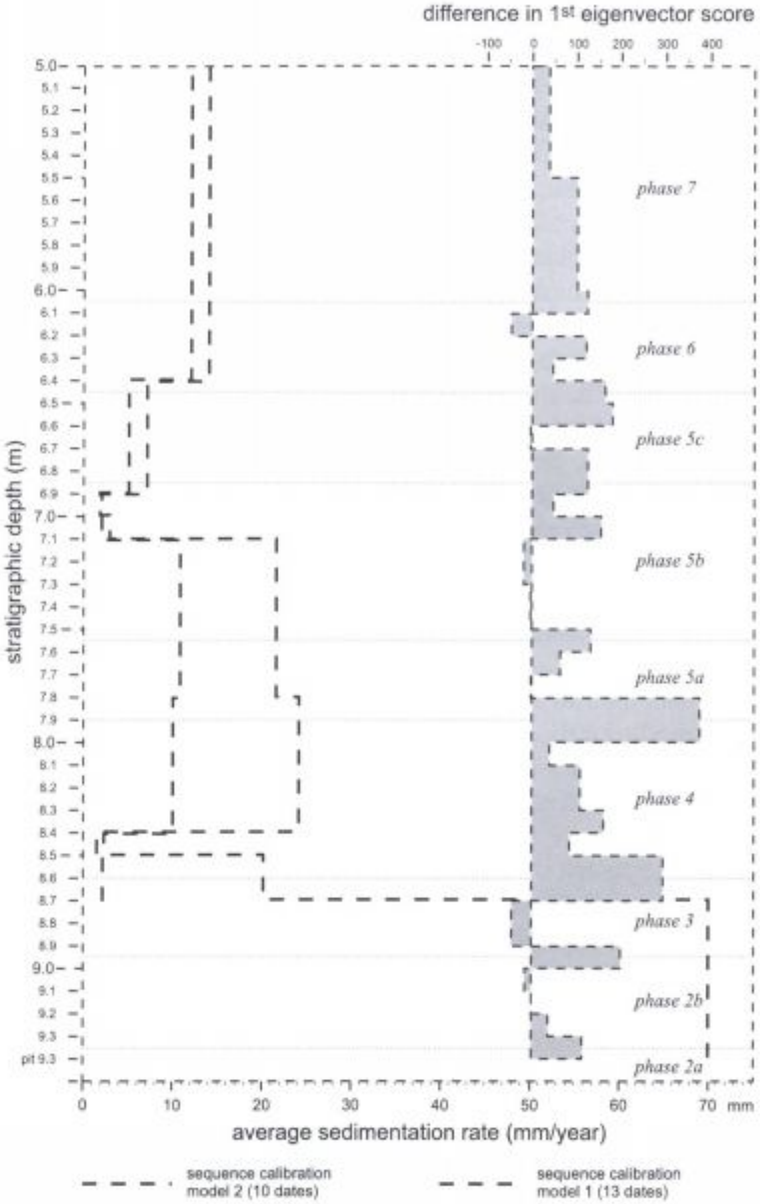

Fig. 8. Correlation of interpolated sedimentation rate and typological change.

The rate of change in pottery composition is expressed by the difference between adjoining stratigraphic units in their first component score of correspondence analysis. For this purpose the same matrix of type frequencies as in Figure 3 was submitted to a *detrended* CA (*Greenacre 1989.232*) in order to express the "typological distance" by one vector only. The shaded histogram in Figure 8 represents the degree of dissimilarity between neighbouring stratigraphic units. Negative values signify that stratigraphic units have been reversed as a result of the seriation. Once again, the coincidence of the phase boundaries with peaks of typological dissimilarity is obvious. The central issue of Figure 8, however, is the correlation between sedimentation rate and typological change, which leads us once again to the question of cultural dynamics and/or accelerated settlement growth. Starting from the bottom, we can see a coincidence of slow sedimentation (according to dating model 2) with a high rate of pottery change between ▼ 8.7 and 8.5 m. Increased sedimentation above this level correlates with decreasing change in the type assemblages until ▼ 8.1 m. Between ▼ 8.0 and 7.8 m, the highest degree of dissimilarity of all adjoining levels can be observed, followed by a marked drop. For the overlying 70 cm of tell accumulation, only small differences between neighbouring levels occur, which made it difficult for the seriation to sort these units in the correct order with respect to their type composition. Above ▼ 7.1 m, a similar pattern reappears as below ▼ 8.0 m: low sedimentation correlates with higher rates of change. Accelerated sedimentation, occurring around ▼ 6.4 m, is met by a peak in typological change.

Three basic patterns can be observed in Figure 8: the rate of sedimentation and typological change between stratigraphic units can be negatively correlated as between ▼ 8.4 m or around ▼ 7.0 m. Such an inverse relation would be considered normal, as artificial stratification units from slowly sedimented layers comprise more time and therefore greater differences in type composition. Between ▼ 8.4 and ▼ 7.1 m sedimentation and typological change are uncorrelated: in the lower part, moderate change coincides with a constantly high sedimentation rate. Between ▼ 8.0 and ▼ 7.8 m sedimentation remains almost constant, the exceptional dissimilarity in the type composition of these two levels can thus only be explained as an *innovation horizon*. It coincides with the end of the first building phase, represented by 6 houses discovered between ▼ 8.3 and ▼ 7.9 m whose horizontal position is unknown (*Stalio 1968; 1984.35–37*). The overlying 70 cm of sediment appear to have been accumulated at still the same speed as before, but there was little change. The type composition remains fairly homogenous and the stratification units are therefore difficult to distinguish statistically. So apparently this period has to be interpreted as a *stagnation phase* rather than as *compressed time* caused by rapid sedimentation.

Even more difficult to interpret is the pattern above ▼ 6.6 m. Obviously, there is a certain amount of innovation occurring around ▼ 6.5 m, the effect of which is, however, counterbalanced by increased sedimentation above ▼ 6.4 m. The interpolation of settlement growth is probably not accurate enough here, because it is based on only two radiocarbon dates from the levels ▼ 6.4 and ▼ 4.1 m. On the other hand, however, some of the few known and published house inventories come from the levels ▼ 6.8 to 6.5 m, and during the following 50 cm until ▼ 6.0 m a major replacement of pottery types is well documented (*cf. Garašanin 1979.150–152; 1973.95–96; 1993.13–15*). This could plausibly have resulted from a destruction and levelling horizon after the end of the settlement around ▼ 6.6 m, which accumulated half a meter of debris in a comparatively short time. On top of it, probably the first houses of the next building phase were constructed, the positions and contents of which unfortunately are not documented. The premature occurrence of new pottery types below ▼ 6.0 m could result from pits belonging to the later settlement, which were not recognised during excavation.

The combined statistical analysis of the gradual change in pottery type frequencies and recent radiocarbon results may thus help to distinguish between cultural dynamics and the accumulation process of settlement debris. Interestingly, some discontinuities in the development of the pottery, which CA revealed, correspond quite well with building phases, which were reconstructed with reference to the unpublished notes and sketches of the excavator (*Korošec 1953; Stalio 1968; 1984*). Phases 5b and 5c of the present study (Fig. 4) coincide with B. Stalio's settlement III, while her settlement IV covers both phases 6 and 7. The stratigraphic boundaries of phase 5a to 7, as defined here, show surprisingly good accordance with Korošec's layers IIa, IIb, IIc, IId and III (*Korošec 1953.41–44*).

Many problems and open questions about the sequence of building phases in Vinča-Belo Brdo can be solved only by means of new excavations, which would require large areas and a corresponding investment of funds. But for the time being, a statistical analysis of both relative and absolute chronology, based on the old finds, can improve our understanding of the settlement history of one of south-eastern Europe's largest tell sites.

ACKNOWLEDGEMENTS

The results presented in this article were part of a research project supported by the Deutsche Forschungsgemeinschaft. I wish to thank Dr. Bernd Kromer, Heidelberg for performing the radiocarbon analyses and his information about the OxCal program. Prof. Dr. Irwin Scollar, Remagen supported the project by providing test versions of his archaeological statistics program WinBASP. PD Dr. Paul Yule, Bonn was kind enough to go over the English version of this text.

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