Donk Dissection: spatial attribution through reprojection of Hazendonk Unit C

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The purpose of this study was the development and successful implementation of spatial analysis through reprojection. The method was devised to cope with an orientational problem of a coordinate system used at the excavations of the Hazendonk, a Neolithic site in the western Netherlands. Misalignment of the axes (related to the most important find complex), combined with lacking lithological layer attribution of the finds in situ made dissecting the artefact clusters into archaeologically relevant units impossible, shielding a potentially rich database from further investigation.

Ultimately, through three dimensional modelling based on lithological interpretations of stratigraphy a correction factor was found to rotate the original coordinate axes, dispensing with one dimension in the process. The remaining two made correct cross section views of the artefact clusters possible, as well as relating them to stratigraphic features and each other. Thus distinct concentrations of artefacts could finally be identified and related to archaeologically defined culture phases.

1. Geomorphology

If archaeological aspects of prehistoric settlement in the western Netherlands are to be examined, the interpretation of the geomorphological development of the landscape is often essential, for few regions in Western Europe have undergone as many changes in their natural environment during the post-Pleistocene era (Louwe Kooijmans 1974). Nearly half the deposits covering the Dutch landscape date from the Holocene (Hageman 1969; Zagwijn 1986), often carried to the region by large rivers. Rhine, Meuse, and Scheldt spread out in the flatlands to form a delta, creating an irregular triangle with its apex near Nijmegen and its base along the Dutch coastline (Louwe Kooijmans 1987). Between the eastern river clay area and the western sea clay area extensive peat bogs, formed during the Atlantic, remained relatively undisturbed through much of the Holocene. Particularly the southern half of this area (the Alblasserwaard) always remained a tidalfree freshwater environment (Van der Woude 1981). This wetland region was doubtless rich in wildlife and easily accessible over water.

When Neolithic man came to hunt, fish and gather, he sought a dry refuge to venture from into the wilds, to use as a seasonal hunting basecamp or even for permanent inhabitation. He settled on *donken*, the surfacing tops of riverdunes (Verbraeck 1974). These dunes were formed in the dried out riverbeds of the Rhine and Meuse rivers, as a result of aeolic deposition of river channel sands. This deposition took place up until the Boreal, when the younger sediments of peat and clay started covering the sides under the influence of the rising waterlevel. When further aeolic sedimentation was prevented by the increasing wetness of the river valley the dunes became a fossilised part of the landscape. The post-Boreal sedimentation sequence was characterised by a succession of peat formation and clastic sedimentation by lakes and creeks (Louwe Kooijmans 1982; van der Woude 1981).

Though the base of the prehistoric settlements was presumably made on the dry top, former living areas extended downslope and into the surrounding sedimentation zone. There surfaces and refuse concentrations are well preserved in and between the Holocene deposits covering the slopes. (Louwe Kooijmans 1982).

The *Hazendonk* had good prospects to become an interesting archaeological site. Sedimentation had covered occupational refuse soon after deposition. Up to ten meters of Holocene peat deposits right next to the donk created favourable conditions for palynological research (Louwe Kooijmans 1980). In addition, the Hazendonk is both small and isolated, resulting in densely concentrated artefact scatters.

2. Excavation

After amateur finds and test excavations had indicated repeated human influence in the immediate vicinity of the donk, a more thorough, large scale investigation took place during three campaigns of the National Museum of Antiquities under Dr. Louwe Kooijmans in the period 1974-1976. Both the dune top and the slopes were tested for Neolithic artefacts in an effort to establish the nature and extent of the different settlement phases. The excavation eventually yielded over 30,000 finds, which were plotted in three dimensions. In view of the extension of the site, the amount of refuse, the thickness of the archaeological layers and the typological variation of the pottery, seven culture phases were postulated, ranging from Hazendonk 1, 2 and 3 through Vlaardingen 1a, 1b and 2b to Bell Beaker (Louwe Kooijmans 1976). See the Rommertsdonk-article of M. Verbruggen in this volume for the latest postulated calibrated radiocarbon datings of these archaeological layers and a map of the Hazendonk region.

The most important location was the pit complex known as Unit C; ten pits on the eastern tip of the donk. There traces of no fewer than five of the seven postulated culture phases (Hazendonk 1, 2 and 3, and Vlaardingen 1a and 1b) had been found in dense scatters covering several pits. This location became the foundation for the chronological sequence of regional culture phases.

Unfortunately a serious problem related to Unit C had arisen during excavation. The Hazendonk's roughly elliptical body is oriented NE-SW, with steep slopes on the northeastern side and a long stretching, southwest pointing tail. Taking into account that all pits had to be relative to one grid, the orientation of the axes of the coordinate system followed the elongated sandbody, to keep as many pits as possible oriented perpendicular to the slope contours. It was believed existing computer technology would be able to solve any orientational problems of pit locations suffering from shifted axis perspectives. This potentiality soon became reality. Following Murphy's Law, the cross section (or downslope) angle of Unit C — the most important find complex — was located almost precisely in between the two axis angles. No matter which of the two axes was disregarded, looking at Unit C from the south or the east created a serious distortion as the clay and archaeological layers followed gravity's commandment down the slope and into the peat, whilst the axes continued to follow the compass. To make matters worse, the artefacts had not been given stratigraphic attribution codes *in situ*, which would have enabled the separation of the different archaeological layers even without downslope cross section slice views. After the last excavation season, high hopes of computer capabilities remained unfulfilled, as the moloch database sullenly defied further analysis. After many attempts to correct the distortion the project was laid to rest, waiting for more advanced techniques and technology.

3. Methodology

In 1989 the current Hazendonk research got under way to solve this problem. The investigations can be divided in two unequal parts. During the first phase, the rough data were extracted from the old storage media, chopped up into separate variables and stored in databases. Preliminary statistics were performed to get to grips with the problem. Finally a strategy was devised to deal with the spatial problem using modelling and mathematics. The aim was to link stratigraphy to artefact scatters, to enable establishment of position of all artefacts relative to each other and to relevant layers. Thus, a spatially interpreted layer attribution would be given to each artefact after the fact (that is, excavation), based on density differences.

To this end all finds would have to be reprojected onto a new axis running downslope at the designated location, combining the coordinates of the older EW and NS grid system. This involved three distinct stages:

1. the reconstruction of the relevant stratigraphy to define the correct reprojection angle;
2. the reprojection itself;
3. the analysis of the results, leading to attribution of all artefacts to larger spatial units.

4. Reconstruction

The first step involved the physical reconstruction of the stable donk substratum. The existing datasets could obviously not provide significant information about the subsoil; not only were they part of a different matrix, 'hovering' above the dune; their spatial relationships were also the ultimate goal of the enterprise, and including them in the first step of the solution would create a circular argument. Donk data therefore had to be independent of archaeological interpretations. Two other sources provided the required information. Part of the documentation of a geological survey of the site executed in 1976 still existed, and the lithological descriptions of 102 borings were among the material, as was a map of their positions. These locations were digitised in AUTOCAD and stored in a database with their respective depths of the donk sand. The second source of donk data was even more concentrated around the pit complex; these depths were obtained by measurements taken from the pit profile drawings.

The next segment of the process involved the translation of these (484) donk depths into a regularly spaced grid model of the dune surface. This was achieved with the SURFER software package using kriging, which assumes an underlying linear variogram. An area measuring 30 by 30 meters around Unit C was selected for reconstruction (fig. 1). Due to the limitations of the program the generation of an acceptable representation took up a lot of time and made the initially desired resolution of 10×10 cm for each grid cell impossible. Nevertheless, 20×20 cm still seemed dense enough to represent the peculiarities of a landscape area of 900 m^2. One aspect of this analysis was the interdependence of control values from borings and profiles; neither could independently provide enough information about the contours of the sandbody, although the boring rays did an over all better job than the (densely spaced) profiles. Used in conjunction they yielded 22,500

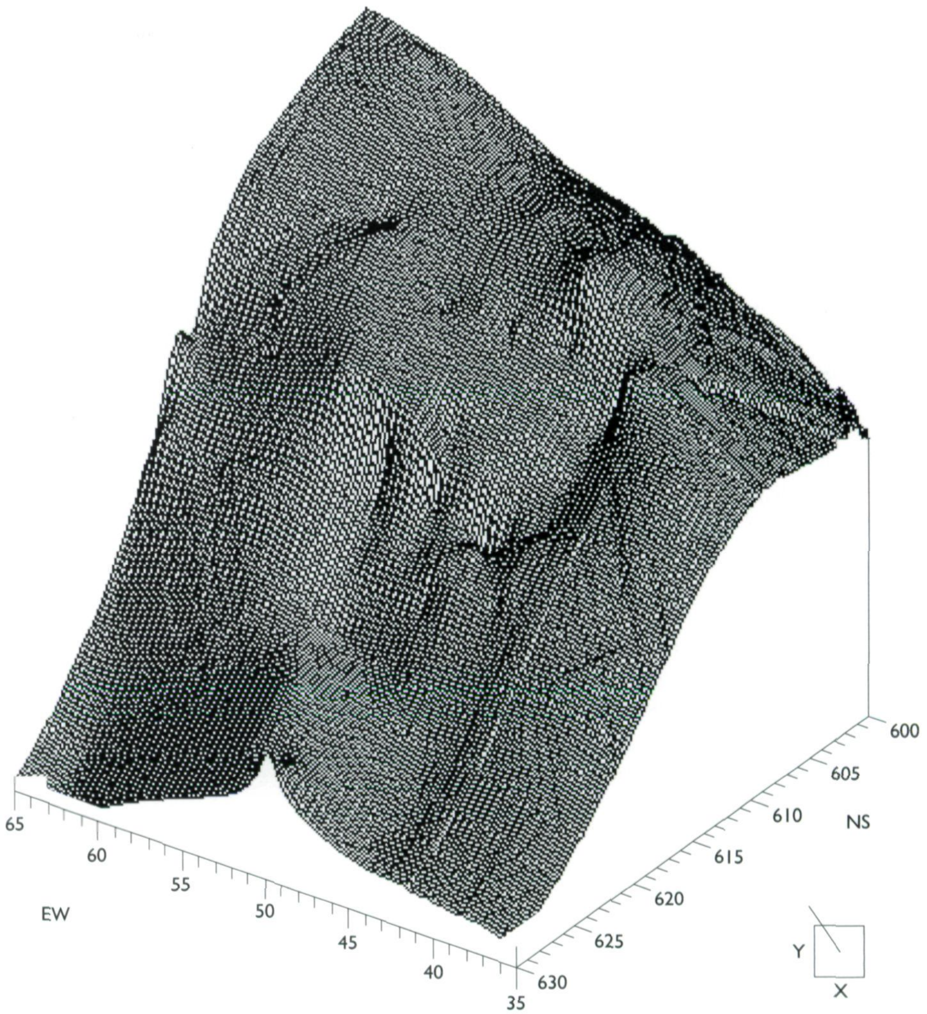

Figure 1. Orthographic projection of Unit C and vicinity (30 × 30 m).

calculated, regularly spaced heights as well as visual interpretations (such as figure 1). Unfortunately, the output of SURFER did not abide by the rules of standard exchange formats, so a separate program (named RECALC) was written to reshape the results into a structured database of three coordinates. This completed the first phase.

5. Reprojection

The second, reprojection stage can itself be split in two parts: the determination of the slope of the slicing function, and the actual reprojection itself.

The first part of the second phase was given substance in another custom made program (REGRES). When given a set of coordinates and a height interval, it would locate the depth of the donk sand at that position on the grid map generated with SURFER. Then it would proceed by searching all nearest points, of which the donk depth was a given multiple of the height interval above and below the central point. These locations were subsequently stored in a separate database. This implied that from each contourline the point nearest to the given location was found and stored (after which the process was repeated with other central locations). These data points were then submitted to simple linear regression analysis in SAS (a statistical analysis software package), resulting in a number of slicing functions through Unit C, perpendicular to the contour lines of the donk. Several functions were finally combined into one averaged function (fig. 2).

Because the slope difference (or angle relative to an axis) between the most diverging functions was relatively small, the local distortions on the fringes of the pit complex resulting from the use of only one averaged function were minimal. In addition, using only one function to reproject all data points had advantages for later software

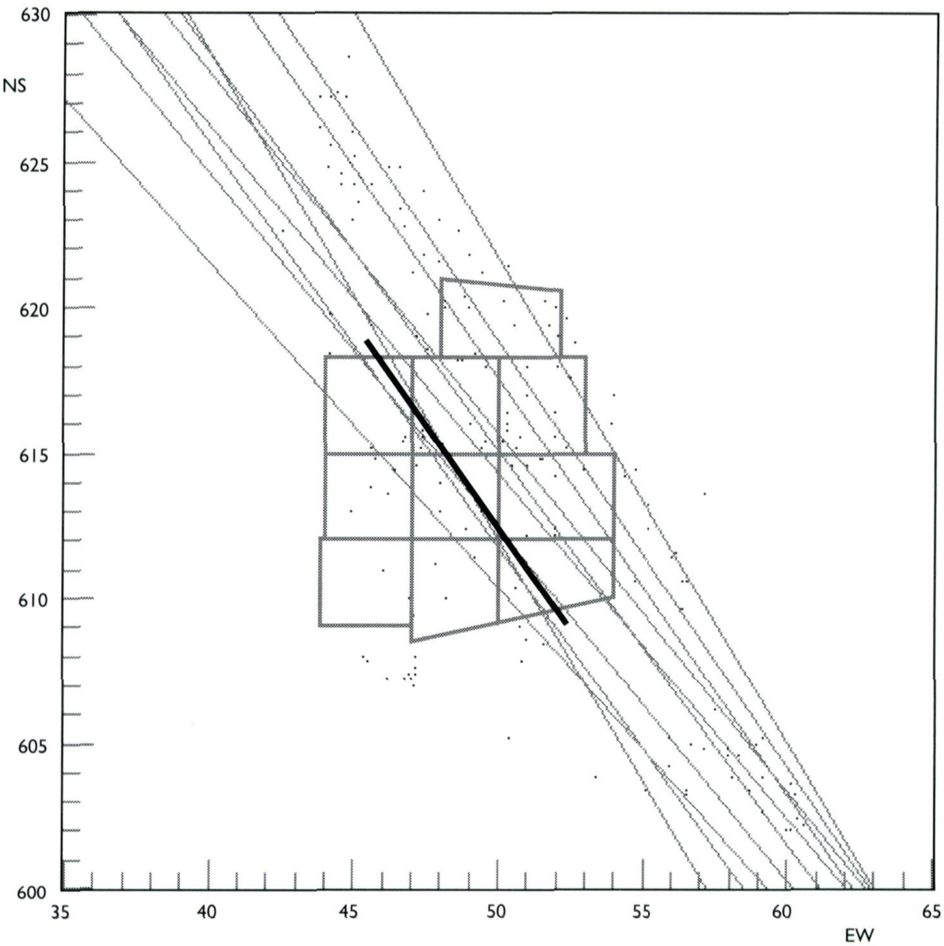

Figure 2. Sample points and regression functions through Unit C. The thick line in the middle is formed by all reprojected (artefact) datapoints together.

implementation. Last but not least, the use of multiple functions fanning out downslope would give rise to a coverage problem; where near to each other, several functions could lay claim to the same data point at a given distance from the function, but far from the top the vectors would be much farther apart. This could create holes in the coverage of data points, and would certainly cause artefact density to drop downslope. For these three reasons only one function was used for all artefacts.

The second step of phase two involved the actual reprojection. Once again this task was performed by a tailor made program (PRO). It involved a dimension reduction; the Cartesian EW-NS grid had to be reduced to one axis. The third, vertical dimension would become the second axis in the reprojection plane. This was achieved by using known artefact data and applying general trigonometric principles (Ayres 1954). Thus for each artefact were recorded (A) its 'plotted' location on the regression function through Unit C, relative to a new origin, and (B) the absolute distance between the data point and its reprojected equivalent. This allowed the artefacts to be ordered from the extreme south northward and made user defined slices of varying density possible, by which the touching and overlap of different spatial units could be controlled. At every position a balance could be struck between the minimum number of points necessary to identify the extent of the visible units, and the maximum Z difference not yet resulting in the mixing of clusters. Since density was relatively uniform throughout Unit C, slices of a fixed number of artefacts could be used throughout the complex, excepting the outer limits (where the number of artefacts notably decreased) and one area where a collapsed profile had created a large gap in the stratigraphy.

6. Dissection

These slices where visualised in the third stage of the investigation using MOLE, another member of the family of software tools developed for the Hazendonk project. It combined graphic displays of reprojected artefacts and the donk subsoil, a dynamic flow analysis, a digitiser to define layer boundaries and a data interface to link output to SURFER.

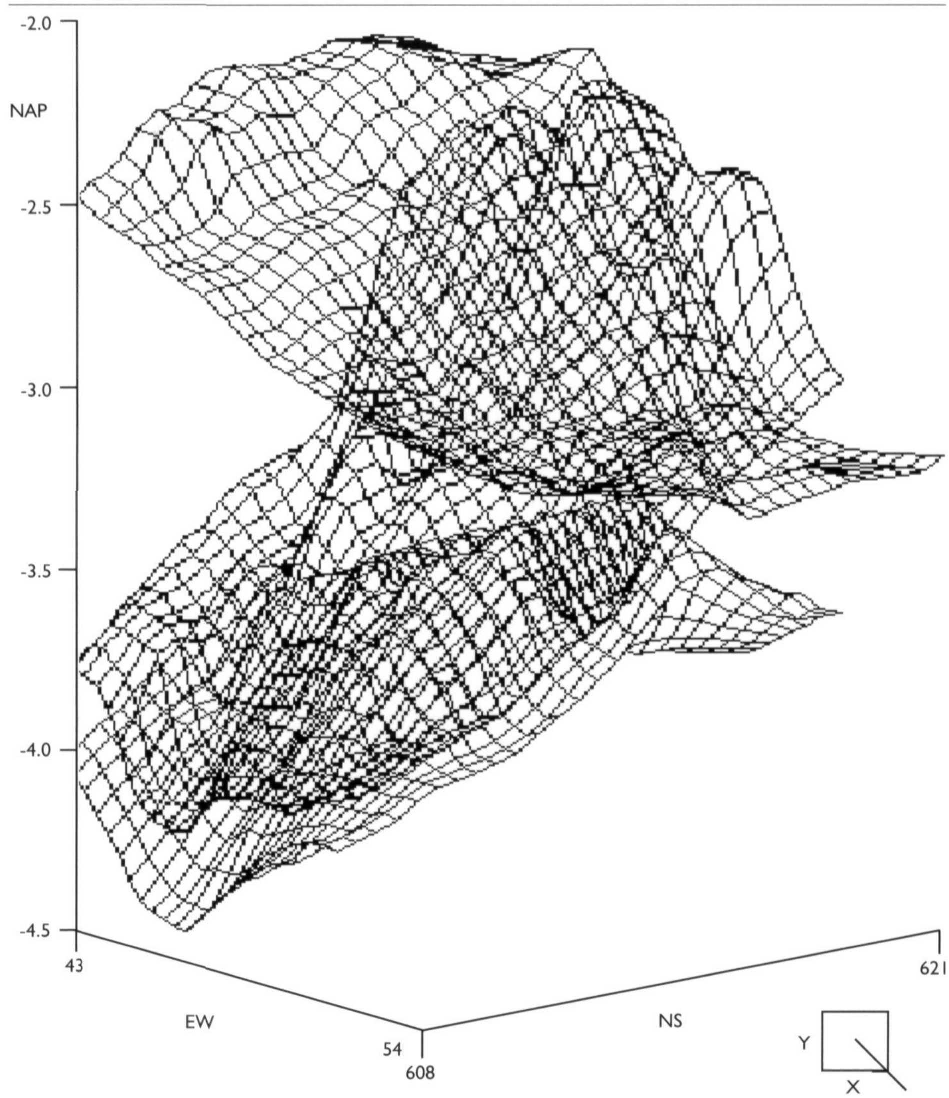

Figure 3. Abstracted orthographic impression of the separator gridnets.

On first examination, the deep southern part of Unit C contained three or possibly four layers (Hazendonk 1, 2, 3, and Vlaardingen 1b), of which the deepest two gradually disappeared when the section was shifted northward. Of the three or four scatters, the second highest (Hazendonk 3) was at places the best defined, clearly separated from the artefacts below and above it. These sterile strata in between provided the key to translating the visual impression into spatial attribution through SURFER. So far, grids generated by SURFER had always represented parts of the landscape. Their similarity to fishing nets, however, helped to inspire a new usage (fig. 3).

If a sufficient number of three dimensional coordinates in the sterile layers between the artefact clusters could be extracted from the MOLE views, these control values could function as hooks to hang a gridnet from, taking the place of the sterile stratum. If the mesh was small enough, a handy fisherman should be able to catch all artefacts swimming above or below the grid. When taken one step further, a system of several nets hovering at different depths simultaneously, could likewise separate all artefacts in one major haul, simply by establishing each artefact's vertical position relative to the different gridnets. This was accomplished with the FISHER program.

Using MOLE's digitiser module reduced the definition of boundary planes to less than an hour's work. Hundreds of points were stored, SURFER calculated dense nets, the program RECALC turned them into databases, which were loaded and combined with the artefact database in FISHER. Of course reality was slightly more complicated. No matter how small the mesh, always there would be dozens of data points, with ostensibly the wrong spatial attribution. When

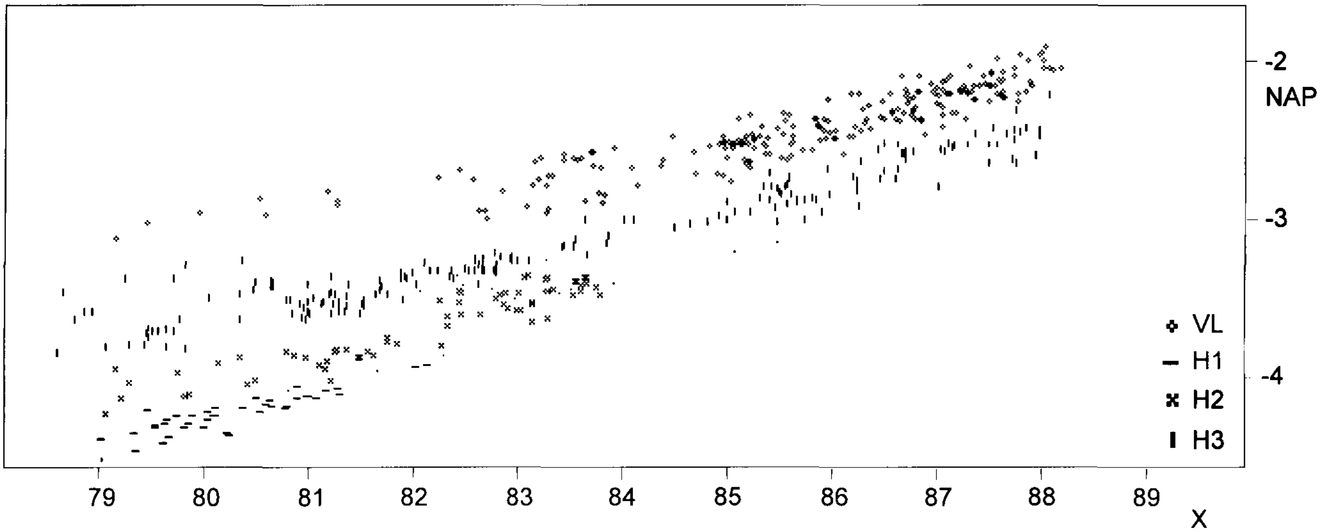

Figure 4. The result of reprojection; a clearly separated Hazendonk 3 level. Above it hovers Vlaardingen material; below two older strata (Hazendonk 1 and 2) can be distinguished. The small dots denote "inbetweens".

seen as the first artefact of a slice, such a point would seem to belong to one cluster, but if the slice was shifted far enough to make it the last one (as hundreds of new points had been plotted on one side and as many had been erased on the other), it would clearly seem to belong to another cluster. This was mostly due to the vertical variation of the different layers. Broadening the slice could not clarify the attribution either; the disputed location then became part of a vague, dense zone of overlap, where even more points seemed wrongly attributed. A satisfactory solution to this problem was not found. In the end 158 (of a total of 6671) datapoints were given separate spatial codes, designating them as inbetweens. This was done by individual encoding of the questionable artefacts (a separate feature of MOLE).

7. Attribution

Although the process was relatively successful, the important question remained to what extent the perceived density differences truly represented local minimums ('sterile' zones, separating different archaeological layers). This was especially pressing in the deep south of Unit C, where a large cluster could be interpreted as consisting of two smaller ones (Hazendonk 1 and 2). Only after detailed density analysis could a local minimum be established, although extremely weak and subsequently difficult to detect. Thus, these two earliest Hazendonk phases were finally (spatially) appreciated as separate density scatters. To what extent the weakness of the separation will lead to a review of the distinction between Hazendonk 1 and 2, which in pottery typology is also rather vaguely distinguished, remains an open question. (Once again I refer to M. Verbruggen's article on the Rommertsdonk, where a more comprehensive analysis of the phasing of these archaeological layers is given in the broader context of donk inhabitation throughout the Alblasserwaard.) The other two strata were labelled Hazendonk 3 and VLaardingen-1b, based on earlier radiocarbon datings, pollen diagrams and typology. No separate Vlaardingen-1a layer could be spatially identified.

When the results of MOLE were deemed satisfactory, another program (BIRD) was written. In internal structure it closely resembled MOLE, but instead of a subterranean view, the old EW-NS grid was resuscitated to generate a bird's eye view of Unit C. Data points were sorted by depth (variable NAP), creating horizontal section views of specified thickness. BIRD also identified another few points with obvious incorrect coordinates, and had the option of showing all artefacts of a selected spatial code. This completed the last stage of the analysis (fig. 4).

8. Discussion

In evaluating the above, a few concluding remarks can be made. The method is only indirectly connected to archaeology. This is both its forte and its weakness. Omitting most earlier interpretations from the analysis (based on stratigraphical and typological characteristics) adds strength to the claims of independent results, but at the same time loses the foundations of a firmly established scientific discipline. A functional approach of the site, incorporating assumptions regarding activity areas (based on specific artefact context) might have yielded better spatially defined units, with a more vivid human component as well. Further typological evidence from related sites could possibly also provide a less sterile picture of regional culture complexes. Subsistence models based on palynological evidence and landscape reconstruction likewise present a vision, whereas this technique only creates a (slightly different) view.

But although the method under review may be limited and lacking something in human interest, it did succeed within the confines of the spatial interpretation. Stratigraphic data were used to build a model, which yielded the desired slope coefficient information. The reprojection itself was successful, and the custom made programs performed adequately to render hitherto unseen (virtual) subterranean images. The angle correction also resulted in distinct, spatially defined artefact clusters, to which over 97% of the data points could be attributed. When combined with knowledge from related disciplines (notably archaeology, paleo-ecology and geology), these scatters can be dated and culturally attributed, thus rendering information on artefact assemblages representative of the phases under investigation.

So finally, over a decade after the end of the initial excavations, the Hazendonk datasets have become available for further analysis, enabling comparison of the spatially defined scatters to artefact clusters from other, similar sites in the region. At long last, computer technology is catching up with expectations raised years ago.

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