Artifact Orientations from Total Station Proveniences

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ABSTRACT

It is well understood that the orientations of artifacts, of fauna, and of the geological constituents of an archaeological layer can be useful in assessing site formation processes. There are a number of ways in which orientations can be recorded. This paper describes a method we have used at a number of Paleolithic sites to, in effect, automatically record artifact orientations while piece proveniencing them with a total station. Two points are recorded for elongated artifacts, and these coordinates are used to calculate the object's orientation (both bearing and plunge). Orientations are then analyzed and plotted using an Eigenvalue method that represents multiple types three dimensional patterning. An example of this methodology is provided here using data from the French Middle Paleolithic site of Combe-Capelle Bas.

INTRODUCTION

It is well understood that an assessment of the orientations of clasts within a deposit can be useful in assessing formation processes (eg. Butzer, 1982; Kluskens, 1995; Kroll and Isaac, 1984; Schick, 1986). This paper describes a method to record artifact orientations while piece proveniencing them with a total station (see also McPherron, 2005). The paper then overviews techniques for calculating orientations from the three-dimensional coordinates produced by the total station and methods for presenting and analyzing them. Data from the Middle Paleolithic site of Combe-Capelle Bas are presented and analyzed to illustrate the method.

Artifact orientations are easier to conceptualize than they are to define and measure. This is because artifacts are complex and typically irregularly shaped three-dimensional objects resting in three-dimensional space. The solution we have adopted is to simplify the problem by focusing only on the orientation of the major or long (a-) axis of artifacts, which is known to be sensitive to some site formation processes. In many excavation contexts it is already standard practice to record the three-dimensional coordinates of every artifact larger than a certain size to create an intra-site GIS. More frequently, this is being done with a total station (Dibble, 1988; McPherron and Dibble, 2002). While experimenting with this method, it became apparent to us that the total station's inherently high level of precision allowed additional data, aside from a single point location, to be captured. Thus, in our excavations, once an artifact is exposed, a decision is made whether to record the artifact's orientation by taking a total station measurement at both ends of its long axis *vs.* a single measurement in the middle. Several elements enter into this decision including whether an artifact's position is disturbed during excavation, whether both ends of the artifact can be clearly seen and measured with the most accurate prism, and whether the artifact has a clear long axis. Numerical criteria are not used to establish whether the artifact has a long axis. This can be done afterwards using the GIS and analysis data on the artifact's size and shape.

If the artifact is appropriate for orientation analysis, then a total station measurement is made at each end of the artifact's long axis. If it is not suitable, then either only one point is recorded at the center of the object or more than two points are recorded to trace its outline. In this way, all two point artifacts in the spatial database can be automatically selected by the GIS for orientation analysis. In other words, the number of points associated with an artifact provenience indicates the type of analysis that can be performed on it. This technique eliminates the need for an additional field in the excavation database to indicate whether the points are intended for orientation analysis and, therefore, eliminates a potential source of error (e.g. the excavator forgets to note that this artifact is suitable for orientations).

1. CALCULATING, PRESENTING AND ASSESSING ORIENTATIONS

The orientation of an artifact's long axis line can be described by the geological terms bearing or trend and plunge (Hills, 1972: 144; Seyfert, 1987: 634). Bearing is the angle, measured horizontally, of the long axis line relative to some geographic or arbitrary north, and the plunge is the angle, measured vertically, of the line relative to the horizontal plane. A plunge angle of 0 represents a line that is parallel to the horizontal plane, and a plunge angle of 90 is a line perpendicular to it. Bearings can range from 0 to 360 degrees. Calculating these angles from a pair of XYZ coordinates can easily be done using a spreadsheet (McPherron, 2005) or with commercially available software. The only minor difficulties to overcome (outlined in McPherron, 2005) are that typically trigonometric functions assign an angle of 0 degrees to the positive X-axis and angles increase counter-clockwise whereas archaeological maps prefer to place 0 degrees along the positive Y-axis (usually north) and angles increase clockwise.

The two primary methods for visualizing orientation data are spherical plotting and circular histograms (Rose Diagrams). In spherical plotting, all orientation lines are positioned such that they pass through the center of a sphere and the point at which they exit the upper or lower sphere is noted on the sphere's surface (Figure 1). The surface points from either the lower or upper hemisphere are then projected onto a two-dimensional circular diagram using one of two methods: stereographic (Wulff) or equal-area (Schmidt) (Seyfert, 1987: 636). Rose diagrams or radial histograms can then be used to visually summarize these data.

Because the resulting data are circular, standard statistical methods for summarizing patterning in these data are not applicable. There are circular statistics designed to account for the either 180 (bidirectional) or 360 (unidirectional) degree periodicity in the data. In the results that follow, a Rayleigh test of uniformity is applied in addition to calculating the mean and standard deviation of the data. This statistic assesses whether the data are uniformly distributed or whether they have a tendency to cluster. Statistically significant results ($p \leq .05$) indicate that the angles are non-uniformly distributed. This statistic alone, however, does not indicate whether the data form a single mode or multiple modes. Rose diagrams are, therefore, critical to the interpretation of significant results. For data sets that show a preferential or modal orientation, a three dimensional mean vector length (L) is calculated. This value expresses the strength of the clustering in the data. Values approaching 0 are weakly clustered and values approaching 1 are strongly clustered.

Finally, Benn (1994) has shown that shape indices calculated from computed eigenvalues (Watson, 1965, 1966; Woodcock, 1977) and plotted on a ternary diagram are useful in distinguishing fabric orientations. Bertran *et al.* (1995) and Lenoble and Bertran (2004) have followed this method and present data from experimentally derived data and from archaeological contexts. Eigenvalues represent the degree of clustering around three mutually orthogonal eigenvectors. The first eigenvector "parallels the axis of maximum clustering in the data" (Benn, 1994: 910). If the eigenvalue for this vector is high and the loading on the next two orthogonal vectors is low, then the data are linear, if the first two eigenvalues are roughly equal, then the data are planar (randomly oriented on a plane), and if all three eigenvalues are roughly equal then there is no preferred orientation and that data are considered to be isotropic (randomly oriented in three dimensions). Each of these possibilities is represented by one pole of the Benn diagram. Note that this approach to orientations has the advantage of simultaneously considering the bearing and the plunge to describe artifact orientations and it is perfectly suited to the kind of a-axis orientation data that the total station method provides (idem, 1994: 910). In an archaeological context, artifacts that plot towards the planar corner are more likely to represent undisturbed deposits.

For this paper, eigenvalues and mean vector length were calculated using StereoNett Version 2.46 by Johannes Duyster. Rayleigh tests were performed with Oriana 2.00 by Kovach Computing Services. Artifact orientation calculations and Schmidt and Rose diagrams were performed with a three-dimensional GIS program authored by McPherron and Dibble (see also McPherron, 2005).

2. ARCHAEOLOGICAL EXAMPLE

The utility of these methods for recording, analyzing and interpreting orientation data can be illustrated with total station data recorded during recent excavations at Combe-Capelle Bas, a Middle Paleolithic site in southwest France (Dibble and Lenoir, 1995; Dibble and McPherron, 1996; McPherron *et al.*, 2005; Valladas *et al.*, 2003). Combe-Capelle Bas is today an open-air site situated on a slope of approximately 25 degrees. Given this slope, one of the main issues with the site quickly became site formation processes and assessing the effect the slope on the archaeology. Several lines of evidence, including the geological data, artifact edge damage, the density of finds in the screens, and artifact orientations, were used to assess site formation. The artifact orientations were previously reported by Kluskens (1995) using different methods of analysis and presentation.

The artifact orientations for the lower sector at Combe-Capelle Bas are presented in Figures 2 and 3 and in Table 1. All but three levels show a preferred bearing, and in all but once instance (Level I-1C1) it is with the slope of the hill (180 degrees is towards the base of the hill). Plunge values are also non-randomly patterned showing an average angle that is less than the average slope of the hill meaning that they are slightly imbricated. It is clear from these data is that slope related processes have altered the archaeological record. There is a strong relationship between the degree of slope and the strength of the clustering in artifact orientations as measured by the vector magnitude statistic L (Figure 4).

What is clear from the Benn diagram is that the levels do not plot in the planar pole and, therefore, show patterning in their three-dimensional orientations indicative of post-depositional movement. What is less clear in this case is the agent since some agents produce similar patterns (Kluskens, 1995; Lenoble and Bertran, 2004). In general, the patterns fit either solifluction (Kluskens, 1995) or debris flow (Bertran and Texier, 1995). Both of these processes produce alignments that range from planar to linear, though debris flow may produce higher levels of isotropy. The Benn diagrams in this case compare more favorably to data for debris flow but overlap with solifluction (Benn, 1994; Lenoble and Bertran, 2004).

3. DISCUSSION

Where total stations are already being used to record artifact proveniences, recording an additional measurement for elongated artifacts provides useful information on artifact orientations that can be used to assess site formation processes.

Orientation data alone are typically not sufficient to assign a particular formation process to the deposit because multiple processes have similar effects. However, artifact orientations are a useful supplementary line of evidence and can often provide an initial, quantitative confirmation that there is patterning indicative of post depositional movement. In the case of Combe-Capelle Bas, for instance, the orientations quickly confirmed the impact of the slope on the deposits. What the orientation data cannot determine, however, is how far the artifacts have moved and what the impact of this movement may have had on the behavioral potential of the site (Bertran and Texier, 1995; Kluskens, 1995; Dibble, 1995).
When working with orientation data, there is no single approach that is always best suited to present and analyze the data. Benn diagrams are generally effective at describing structure in three dimensions, and Schmidt and Rose diagrams are important tools for visually summarizing orientations. In particular, the combination of Schmidt and Rose are very effective for showing overall directionality, Schmidt diagrams show the degree of plunge by bearing, and Rose diagrams are particularly effective for identifying the modal and bimodal patterning indicative of, for instance, fluvial processes. As for the latter, it is known that the eigenvalue method on which Benn diagrams are based is not well suited to data with multiple modalities (Woodcock, 1977: 1235).

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FIGURES

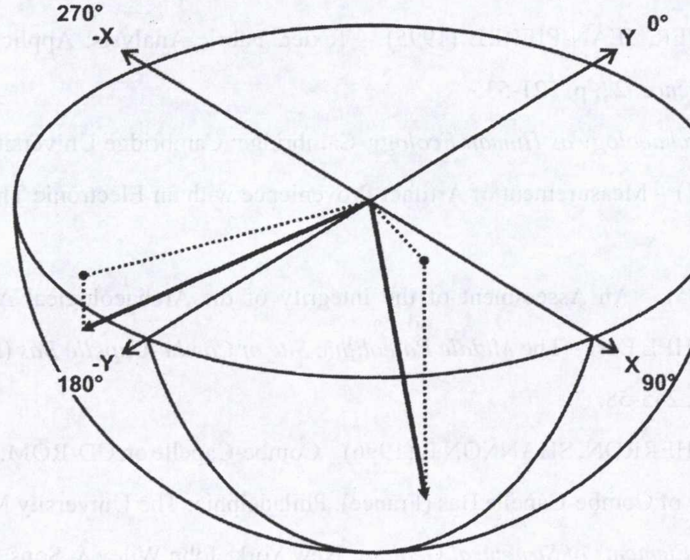

Fig 1 – The lower hemisphere of a Schmidt diagram is represented in three dimensions. To create this diagram, artifacts are positioned such that their highest point is at the center of the sphere. Where the opposite end of the artifact would then intersect the edge of the sphere is noted and then projected onto the circular top of the hemisphere. This two dimensional circular surface is a Schmidt diagram. Artifacts that are lying almost flat will plot near the edges and nearly vertical artifacts will plot towards the center.

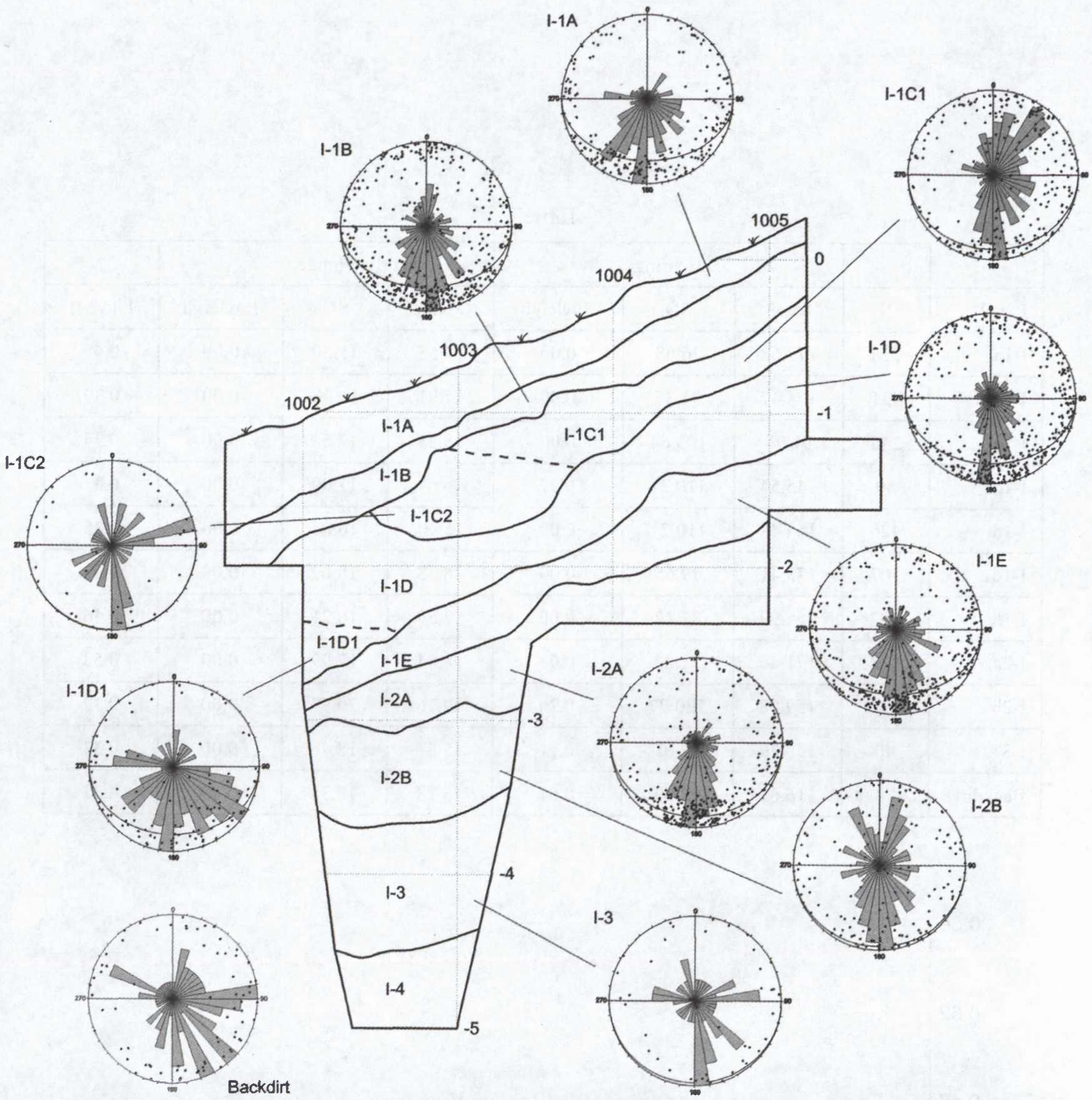

Fig 2 – Schmidt diagrams (low hemisphere) with Rose Diagrams for Combe-Capelle Bas. Data based on Dibble and McPherron 1996.

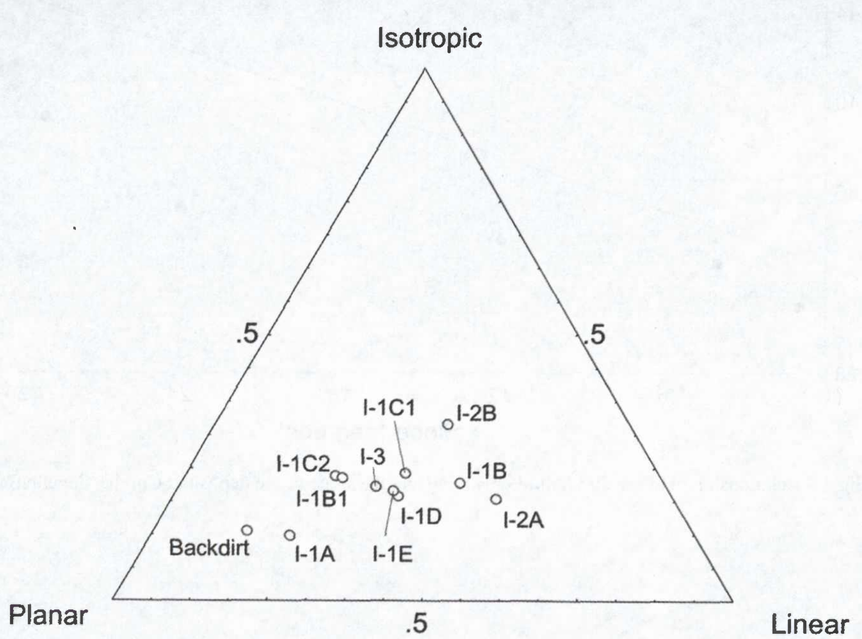

Fig 3 – Benn diagram for Combe-Capelle Bas.

Table 1

		Bearing			Plunge			
Level	N	Mean	SD	Rayleigh	Mean	SD	Rayleigh	L (VM)
I-1a	228	177.68	76.68	0.00	14.55	11.80	0.00	0.45
I-1b	431	174.47	91.37	0.00	17.91	16.63	0.00	0.39
I-1c1	246	91.94	103.64	0.00	18.23	17.53	0.00	0.34
I-1c2	40	145.54	110.21	0.37	16.61	17.00	0.00	0.31
I-1d	426	154.48	110.21	0.00	15.90	16.85	0.00	0.35
I-1d1	107	173.41	79.65	0.00	18.33	18.02	0.00	0.45
I-1e	402	165.99	81.12	0.00	17.59	16.21	0.00	0.46
I-2a	328	171.46	71.82	0.00	18.84	17.99	0.00	0.53
I-2b	137	159.08	120.97	0.20	19.16	20.77	0.00	0.32
I-3	40	150.70	97.63	0.11	15.31	18.46	0.00	0.33
Backdirt	74	116.62	96.29	0.01	13.23	10.38	0.00	0.32

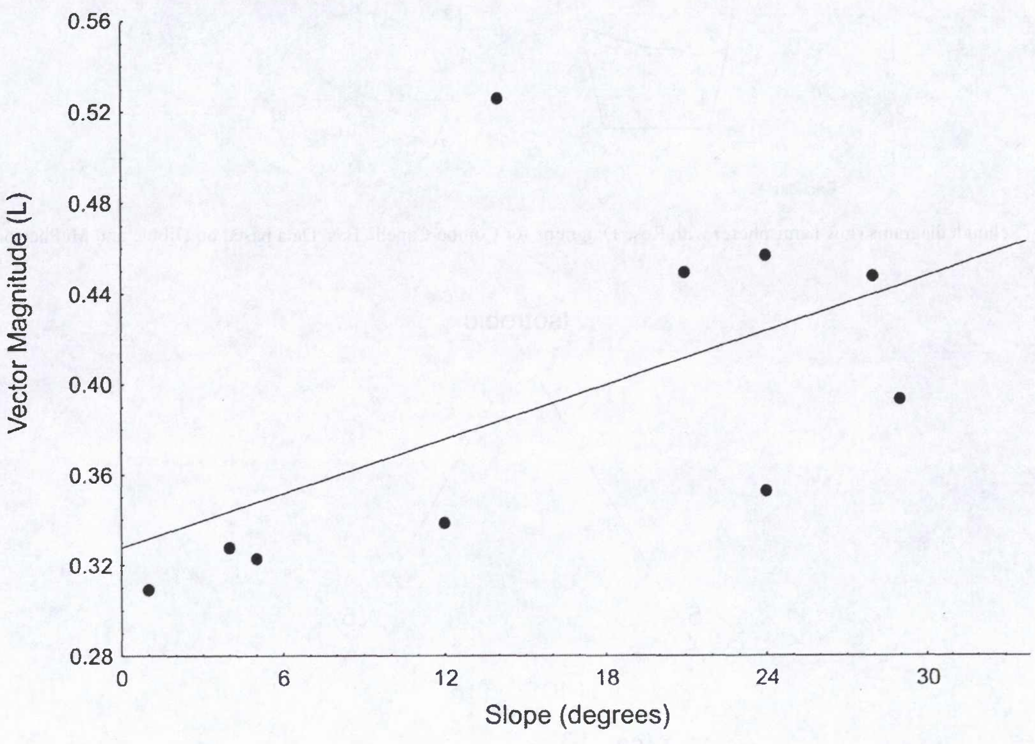

Fig 4 – Relationship between strength of clustering and the slope of the deposit at Combe-Capelle Bas.