A proposal for graphic presentation of orientation data from fossils

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ABSTRACT

Rose diagrams and stereographic projections are the two most popular methods of graphically presenting orientation data of fossils. Of these two methods, stereographic projections present much more objective information to the viewer without any of the subtle subjectivity inherent to rose diagrams. Further, contouring of data point density on stereographic projections, a relatively quick and simple method, serves to highlight any pattern which may be present on the projection.

INTRODUCTION

Geologists have long been studying the spatial orientation of inorganic and organic sedimentary particles to help interpret the origin of sedimentary rocks. (Potter and Pettijohn [1977] provide an excellent review of the concepts underlying grain orientation studies.) Graphic presentation of orientation data has largely been by either of two methods, a rose diagram or a stereographic projection. For example, rose diagrams were used by Lawton (1977), Hunt (1978), Shipman (1981), Shipman et al. (1981), and Kreutzer (1987), while stereographic projections were used by Toots (1965a, 1965b), Voorhies (1969), Saunders (1977), Hunt (1978), and Fiorillo (1987).

The appropriateness of the usage of a rose diagram in orientation analyses can be determined after making a basic distinction between two types of fossil occurences. If the distribution of fossils is dominated by a bedding plane or some other sedimentological interface, then any observed plunge is a function solely of irregularities within that interface. In cases like these where only the azimuth is relevent, which is perhaps best exemplified by shell pavements, rose diagrams can be appropriate.

If, however, fossils penetrate a sedimentological interface then one is dealing with true three-dimensional-orientation data. These data are best treated by plotting the data points on a Schmidt equal area net, which provides the necessary information to the viewer. Most quarry concentrations of fossil vertebrates in fluvial sediments (e.g. Voorhies 1969; Hunt 1978; Fiorillo 1987) belong to this group.

PREVIOUS METHODOLOGY

Shipman (1981) presented general models for idealized fossil orientation as rose diagrams which are respectively: (i) a single preferred axis, (ii) mutually perpendicular axes, and (iii) random distribution. The models she presents are limited by the fact that rose diagrams are capable of portraying only azimuths and exclude plunge data. It should be noted that Shipman's random distribution model is better described as an even distribution because all of the azimuths on the diagram are represented equally (Shipman, 1981, p. 74). (Note, however, that on the next page of the same book she presents rose diagrams, produced from a random number program, which more closely approximate random orientation.) Use of the mirror image rose diagram is advocated in Shipman's book and the diagrams are evident in the work of others (e.g. Kreutzer, 1987). Although mirror-image rose diagrams may be the appropriate way to illustrate orientations of fossils that show no polarity, that is both ends of the fossil are similar such as crinoid stems, I believe they are more typically misleading. These diagrams are certainly inappropriate for fossils which have a polarity showing a significant difference between the two ends of a fossil such as high-spired grastropods or certain vertebrate limb elements like tibiae. An assemblage of these types of fossils must have orientations measured consistently, and this consistency is not expressed in mirror-image rose diagrams. In addition, such diagrams not only ignore the vertical component of orientation, but also, as noted in passing by Shipman (1981, p. 71), "a unimodal distribution, divided within its peak, will appear to be clearly bimodel." Another objection to rose diagram presentation for data from fossils is that by manipulation of class midpoints and widths, subjective interpretation may be introduced. Stereographic projections, as shown below, present orientation data without having to incorporate any of the problems inherent to rose diagrams.

Toots (1965a) pointed out that fossil orientation data, being three-dimensional, are most accurately presented in the same manner as other petrofabric data, i.e., by stereographic projections. These projections provide a means by which three dimensional orientations can be considered as lines within a unit sphere. The points where the lines intersect the sphere, projected onto the horizontal plane, form the stereographic projection. The density of the points can then be contoured on the projection diagram, which serves to further enhance any patterns provided by the orientation data. Interpretation of the orientation data on a projection can be made by realizing that the points around the periphery of a projection represent shallow plunging linear features, while those points toward the center represent near vertical linear features. This method is described in detail in many structural geology texts (e.g. Davis, 1984, pp. 81-86).

As part of his concise review of the general subject of fossil orientation, Toots (1965a) illustrated four idealized distribution patterns of fossil orientations using stereographic projections and commented on their significance in paleoenvironmental interpretation. Toots' four model distributions are illustrated in Figure 1. A fifth generalized model (Fig. 1c) has been added based on experimental and empirical studies post-dating Toots' work (e.g. Voorhies, 1969).

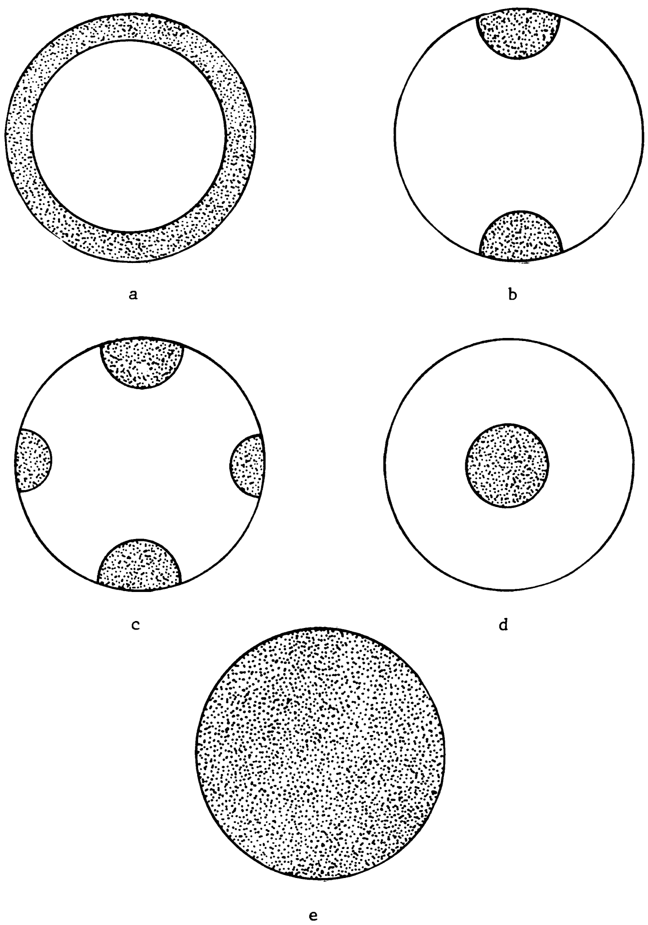

Figure 1. Idealized stereographic projections of potential distributions of orientation data (modified from Toots, 1965a; after Fiorillo, 1987).
a. Non-preferred distribution in an approximately horizontal plane.
b. Distribution with a single preferred axis.
c. Distribution showing two mutually perpendicular axes.
d. Nearly vertical distribution.
e. Random distribution.

A girdle of points evenly distributed around the periphery of the projection (Fig. 1a) indicates a distribution within a horizontal plane but without a preferred direction of alignment. Unimodal and bimodal distributions within the horizontal plane (Figs. 1b and 1c respectively) indicate unidirectional currents aligning the orientations of fossils. Only data satisfying these first three models could be well represented on a rose diagram. A cluster of points in the center of the projection (Fig. 1d) is unlikely for fossil bones, but could result from upright fossil tree trunks. Points evenly distributed throughout the projection indicate randomness in three-dimensions (Fig. 1e). The circumstances necessary for such a distribution to occur would have to provide for many bones or some other linear fossil to be deposited in an unstable orientation, while others were deposited in a stable orientation.

DISCUSSION AND CONCLUSION

The models for a non-preferred distribution within a horizontal plane, a near vertical distribution, and a random distribution would be indistinguishable if presented as rose diagrams, since the latter ignore vertical components of orientation. This point is clearly demonstrated with data from Hazard Homestead Quarry, a mid-Miocene mammal site in southwest Nebraska (Fiorillo, 1987). Orientation data from this site are presented as a stereographic projection (Fig. 2a), a contoured projection (Fig. 2b), and a rose diagram (Fig. 2c). The steeply plunging bones, represented by the points towards the center of each projection (Figs. 2a, 2b) are undetectable in the rose diagram (Fig. 2c). These steeply plunging bones are attributed to trampling activity at the time the site formed (Fiorillo, 1987), a taphonomic process missed by presenting data as the rose diagram. A slight preference in orientation data in the NE quadrant is evident in all three figures, but is most readily detectable in the contoured projection (Fig. 2c).

In view of the limitations of rose diagrams, it is emphasized that stereographic projections are a superior method for presenting orientation data. These projections are especially effective when contouring is used to enhance the pattern observable in the orientation data. The contouring of points, a procedure well known from petrofabric studies and one which requires little additional time, permits ready identification of preferred orientation.

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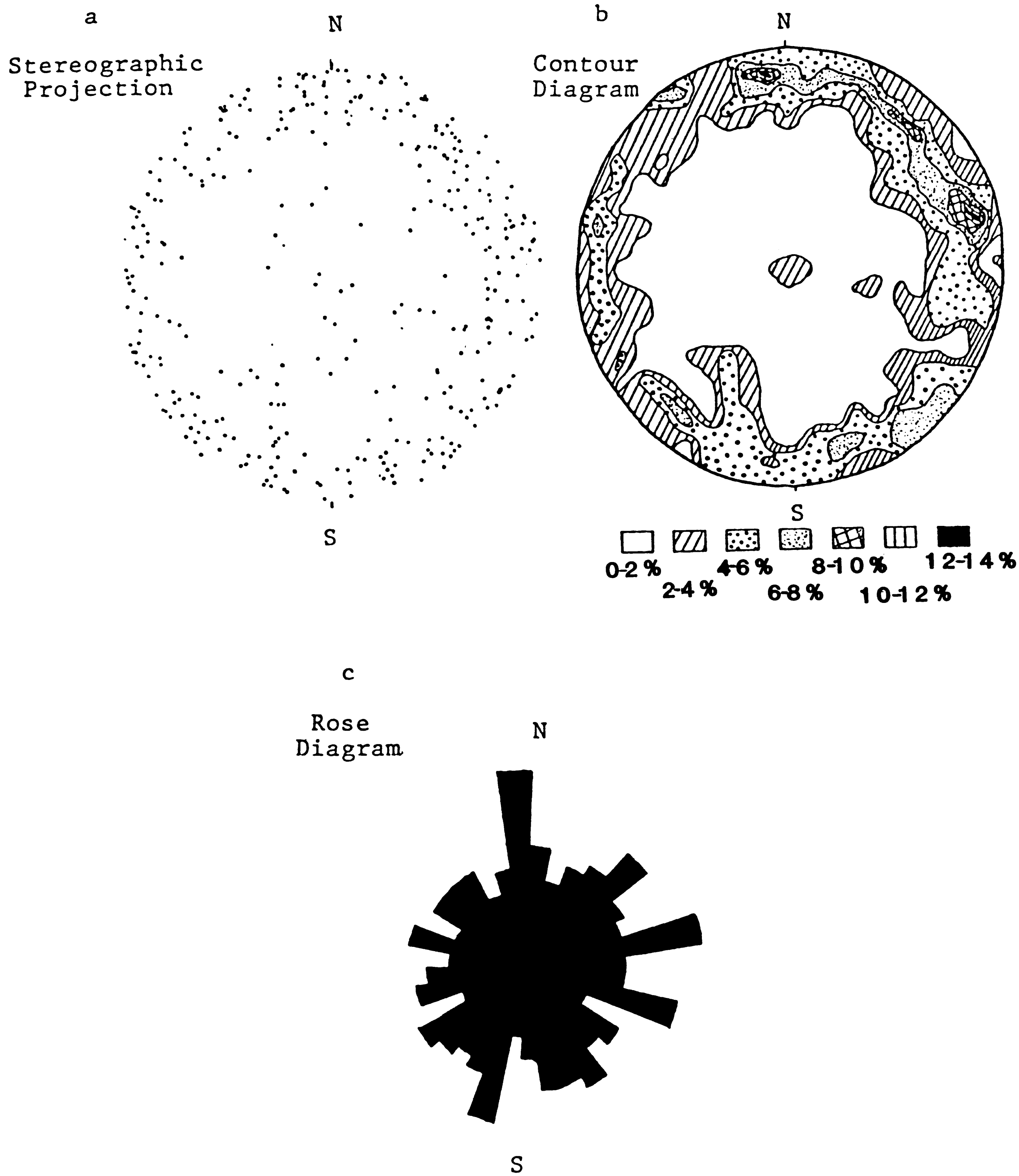

Figure 2. Comparison of different methods of presenting the same orientation data set from fossils. Data (N = 363) from a mid-Miocene mammal site in southwestern Nebraska (Fiorillo, 1987). Notice that the stereographic projection (Fig. 2a) and the contour diagram (Fig. 2b) show the same patterns of distribution as the rose diagram (Fig. 2c) and also include the verticle component of orientation which is lacking in the rose diagram. Also note that by contouring the data as in Fig. 2b, any patterns present in the distribution of the data are enhanced and are more readily observable.

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