The Relationship Between Optical Orientation and Shape Anisotropy in Detrital Gypsum Grains

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ABSTRACT

Gypsum sand from the White Sands dune field of New Mexico has been sedimented in the laboratory and impregnated to study spatial relationship between shape and optical properties of the grains. This sand is dominantly medium-grained and examination of the loose grains show them to be mostly subrounded and tabular.

Petrographic examination of sections of sand, settled in water in a 4 1/2 foot long 4 inch diameter tube and impregnated, confirmed the observation that the gypsum grains are principally tabular. A quantitative measure of oblateness was obtained by statistically comparing diameter ratios in vertical sections with diameter ratios in horizontal sections of the impregnated sand.

A tabular shape would be expected to result from the perfect (010) cleavage of gypsum. Photometric examination, however, under crossed nicols with the gypsum plate inserted shows the grains in a vertical section to be dominantly length-fast. These grains should neither be predominately length-fast nor length-slow if they are tabular parallel to (010). Thus some physical property other than (010) cleavage must be responsible for the observed relationship.

The use of a settling tube to provide preferred orientation of nonequant grains and the statistical determination of an index of oblateness has general application in the study of detrital sediments.

INTRODUCTION

The relation between the crystallographic C-axis and the longest shape dimension in detrital quartz grains has been in controversy for a number of years. The proposal by Martinez (1958) to use a photometer method for studying quartz grain orientation in sandstones has met with some criticism because of his conclusion that there is a statistical parallelism between optic axis and long axis trends in some sandstones. This technique involves measuring photometrically the variation in the intensity of monochromatic light passed through a standard thin section of sandstone on the stage of a petrographic microscope with gypsum plate inserted and nicols crossed during a 360° rotation of the stage. Minimum intensity of light occurs when the trend of the optic axes lies parallel with the slow direction of vibration of light in the gypsum plate. Experimental data were interpreted to indicate that the trend of the long axes of the quartz grains were also parallel with this direction for some samples. This evidence and reasons for this conclusion were further discussed by Martinez (1963).

The principal reason for differences of opinion concerning the relation between shape and optical properties of quartz is the lack of cleavage and the extremely weak tendency for abrasion to result in any shape anisotrophy of the grains. Consequently, any attempt to infer shape orientation from crystallographic fabric was bound to face critical opposition.

It is possible that a photometric study of preferential orientation in windblown gypsum sand may demonstrate more clearly the utility of this optical technique for determination of shape orientation.

The perfect cleavage of gypsum would be expected to result in a marked anisotrophy of the detrital grains. Furthermore, the birefringence of gypsum lends itself to analysis by this technique.

The White Sands dune field of New Mexico is an excellent source of material for studies of this kind. Sand from these dunes could also be used for flume experiments designed to relate shape orientation to current direction. The preferential shape orientation of accumulations of such particles might be very strong when deposited by running water. Therefore, relations between shape orientation and crystallographic orientation could be more positively established than for quartz.

The basis might then be better established for the relation between preferential shape orientation and current direction. Future photometric measurements of quartz sand deposited under these same conditions could be compared to the direction of preferential orientation obtained for gypsum sand. There are two difficulties with this approach. First, the detrital gypsum grains would be expected to be tabular and thus different not only in degree but in kind of response to hydrodynamic forces than quartz. Secondly, gypsum is biaxial rather than uniaxial.

One can argue, however, that tabular grains should show an orientation in the bedding plane similar to elongate particles. Furthermore, it has been demonstrated that the photometric technique can be applied to biaxial minerals of the proper birefringence (Martinez, 1965).

SEDIMENTATION AND SAMPLE PREPARATION OF GYPSUM SAND

The first step has been taken in this investigation. Gypsum sand from the White Sands dune field of New Mexico has been sedimented in the laboratory and impregnated to study the geometric relationship between shape and optical properties of the grains. McKee (1966) in his report on dune structures in the White Sands gypsum, described the sand to range from angular to subrounded with a tabular shape and to be dominantly in the medium-grade size range. Examination of the loose sand used in this study confirmed that the grains were principally medium-grained, subrounded, and tabular.

This sand was sedimented in water in a 4 1/2 foot long 4 inch diameter vertical tube (Fig. 1) to provide preferential orientation. It was then impregnated and sections were cut normal to the axis of the tube (hereafter called horizontal sections) and parallel to the axis of the tube (hereafter called vertical sections)(Fig. 2). Because there was a slight dip to the bedding, one of the vertical sections was cut parallel to the direction of dip and one parallel to the strike.

Figure 1. Sedimentation tube.

GRAIN SHAPE STUDIES

It would be expected that tabular grains would settle with their maximum projection planes generally lying parallel to bedding. This would be reflected by an elongate appearance of the grains in the vertical thin sections with the long dimensions

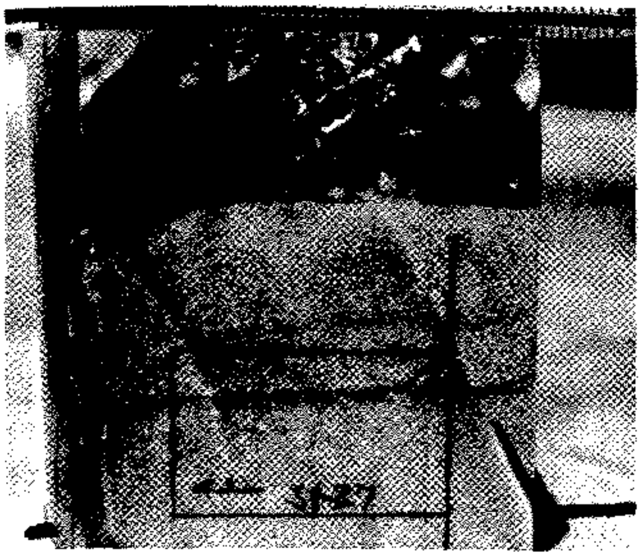

Figure 2. Impregnated sample showing location of oriented thin section.

of the grains dominantly parallel to bedding (Fig. 3). The grains in the horizontal plane should appear roughly equidimensional. Casual examination of the sections give the impression that such is the case. However, a statistical test was applied to attempt to obtain a quantitative measure of oblateness of the grains. Diameter ratios of grains of gypsum in vertical thin sections were compared with those on horizontal sections of the settled and impregnated sand.

Figures 4 and 5 are plots of the distribution of the ratio of the long to short axis in two horizontal thin sections. One hundred grains were measured in each section. The arithmetic mean of these ratios are 1.7 in one section and 1.9 in the other. Figure 6 is a summation plot of Figures 4 and 5. The mode on this plot is a ratio of 1.5 which is smaller than the mean on both of the individual plots. Figures 7 and 8 show the distribution of this same ratio in two vertical sections to have mean values 2.5 and 2.4. The mode on the summary plot (Fig. 9) is a ratio of 2.0.

These data can be interpreted in two ways. The grains can be assumed to have been deposited so that they all lie on their maximum projection plane. In this case one must infer that they are lath shaped, inasmuch as the ratio between the long axis and the short axis of the grains in the plane of the horizontal sections is appreciably greater than one, although distinctly less than the ratio in the vertical sections. The alternative explanation is that these grains are tabular but that a large percentage of the grains lie with their maximum projection plane at some angle to the bedding. Based on the appearance of the lose grains, the second explanation would seem to be correct. It is safe to conclude from these data that the grains are either tabular or lath shaped.

Figure 3. Vertical thin section of gypsum sand sedimented in water.

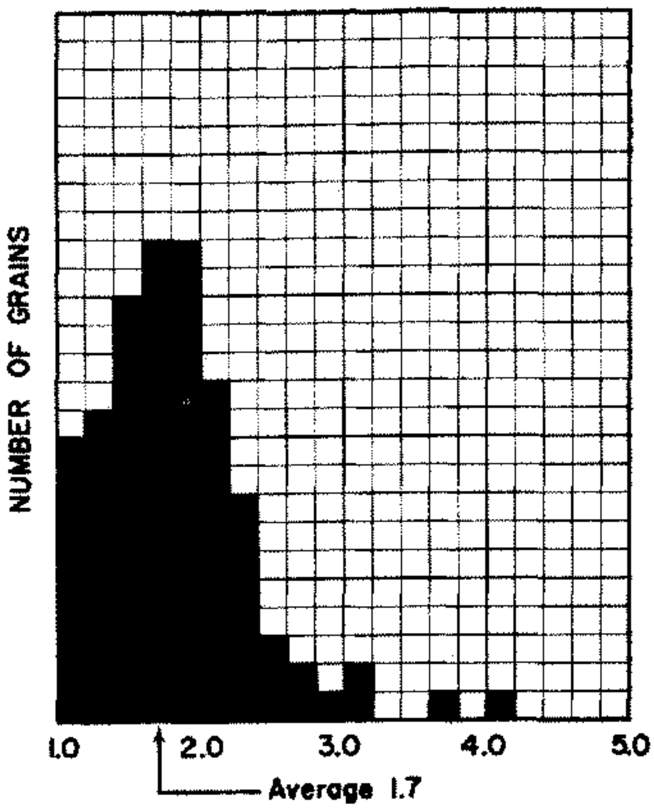

Figure 4. Distribution of the ratio of the long to short axis of grains in horizontal thin section SI 29.

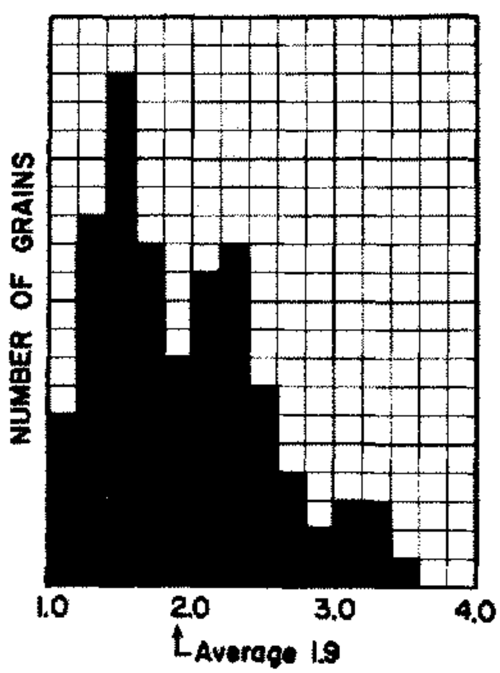

Figure 5. Distribution of the ratio of the long to short axis of grains in horizontal thin section SI 29-A.

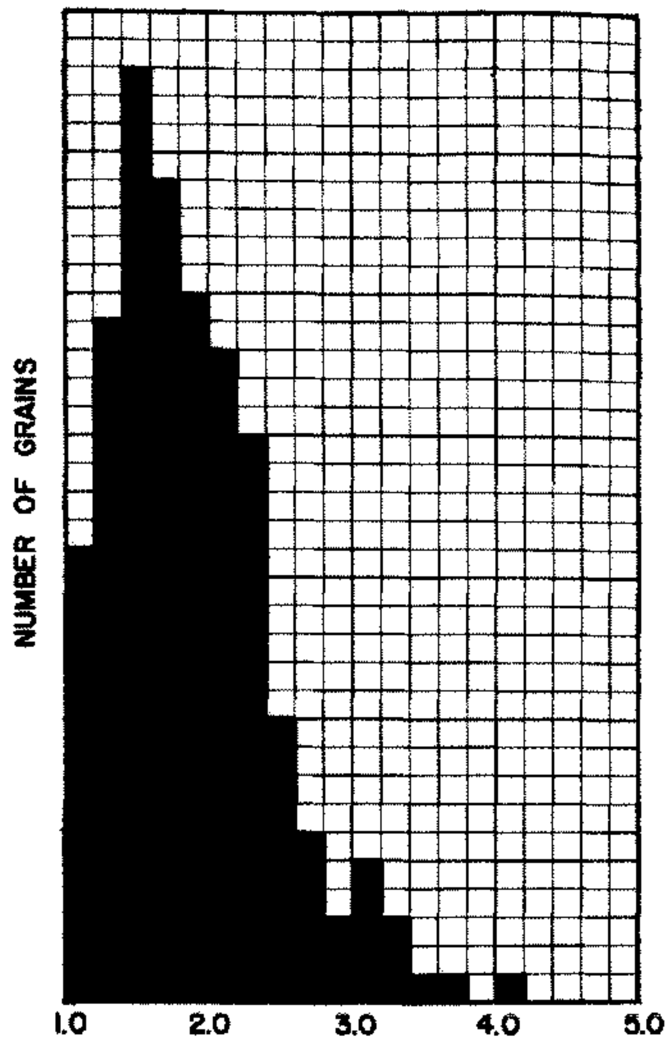

Figure 6. Distribution of the ratio of the long to short axis of grains in horizontal thin sections SI 29 and SI 29-A.

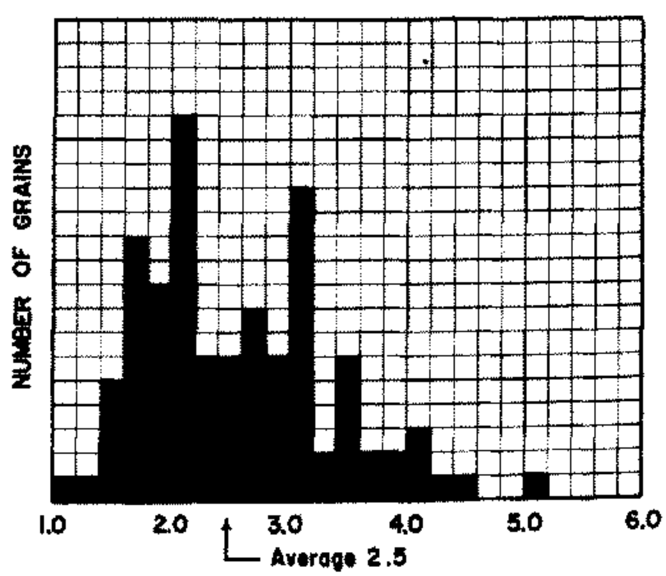

Figure 7. Distribution of the ratio of the long to short axis of grains in vertical section SI 27.

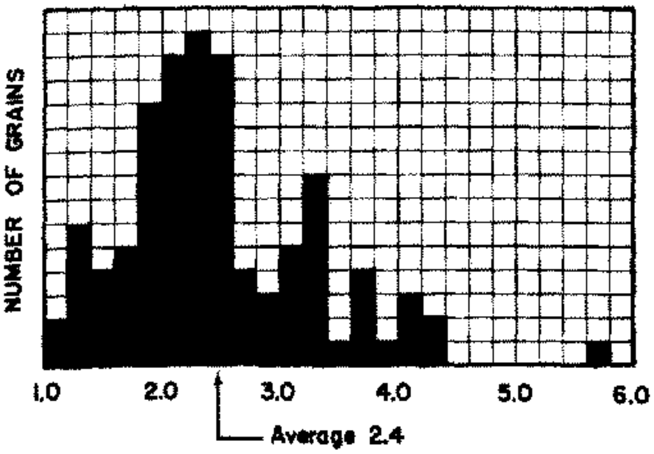

Figure 8. Distribution of the ratio of the long to short axis of grains in vertical section SI 28.

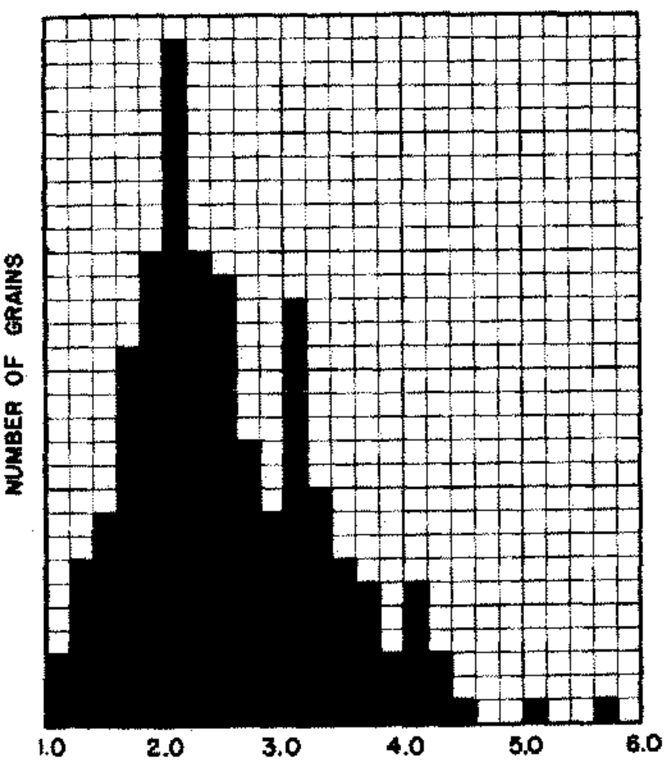

Figure 9. Distribution of the ratio of the long to short axis of grains in vertical sections SI 27 and SI 28.

PHOTOMETRIC STUDIES

Examinations of the vertical thin sections under crossed nicols with the gypsum plate inserted disclosed a strong preferential optical orientation, easily detectable by eye. The trend of the fast rays of the individual grains could be seen to lie generally parallel with the trace of the horizontal plane in the sections. In order to confirm this observation, fast ray-directions obtained from photometric measurements were compared with long axis determination of the gypsum grains. The photometric equipment employed was essentially that described by Martinez (1965).

Figure 10 is a polar histogram showing the results of measurements of the direction of preferential orientation of the long axes of 175 individual grains in one of the vertical thin sections. These data were plotted in 10° class intervals. A procedure similar to that described by Curray (1965, p. 118-120) was employed to obtain the resultant vector of the distribution. This computed resultant vector lies only 7° from the fast-ray trend of the gypsum grains which was determined photometrically. Both the trace of the horizontal plane and of the laminations are even closer (2° and 1° respectively) to the fast-ray trend. The long-axis determinations were obtained along traverses parallel to the trace of the horizontal plane. This attenuates the true preferential orientation. The histogram in Figure 11 shows similar data obtained by making long-axis determinations along traverses normal to the trace of the horizontal plane. This has the effect of enhancing the true preferential orientation, but the resultant vector computed from this distribution should be more meaningful than the one shown in Figure 10. In this plot the resultant vector lies much closer to the fast-ray trend and the trace of the laminations and the horizontal plane.

Similar results were obtained from the other vertical thin sections (Figs. 12 and 13). There was excellent correlation between the fast-ray trend and the trace of the horizontal plane. However, the divergence between the fast-ray trend and the resultant vector and a questionable trace of lamination was greater.

CONCLUSIONS

The results of these comparisons of shape and crystallographic orientation were surprising. It would be expected that the tabular shape of the grains would be a result of perfect (010) cleavage of gypsum. However, the results which have been described show that the grains in the vertical sections are dominantly length-fast. These grains should neither be length-fast nor length-slow, if they are tabular parallel to (010), since Y is normal

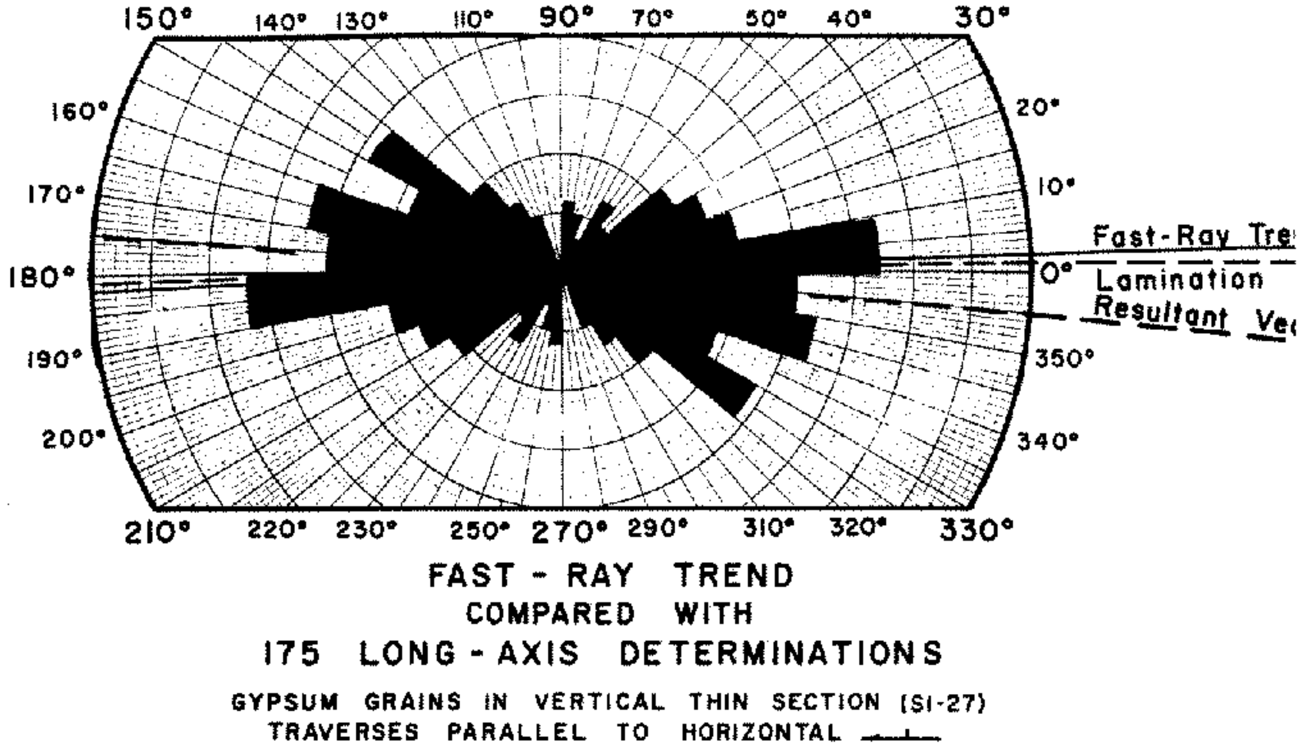

Figure 10. Comparison of fast-ray tend with direction of preferential shape orientation, lamination, and the horizontal for vertical section 27.
erses parallel to horizontal.

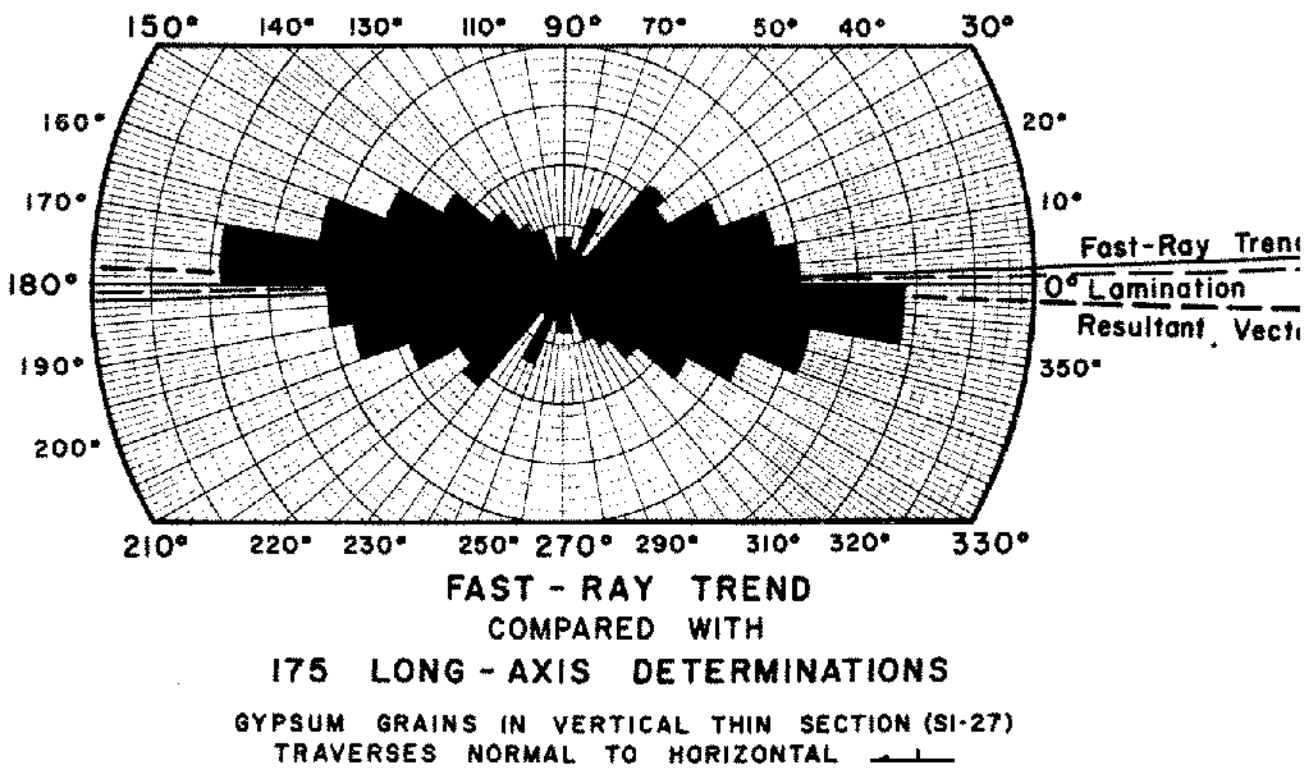

Figure 11. Comparison of fast-ray trend with direction of preferential shape orientation, lamination, and the horizontal for vertical section 27. T
erses normal to horizontal.

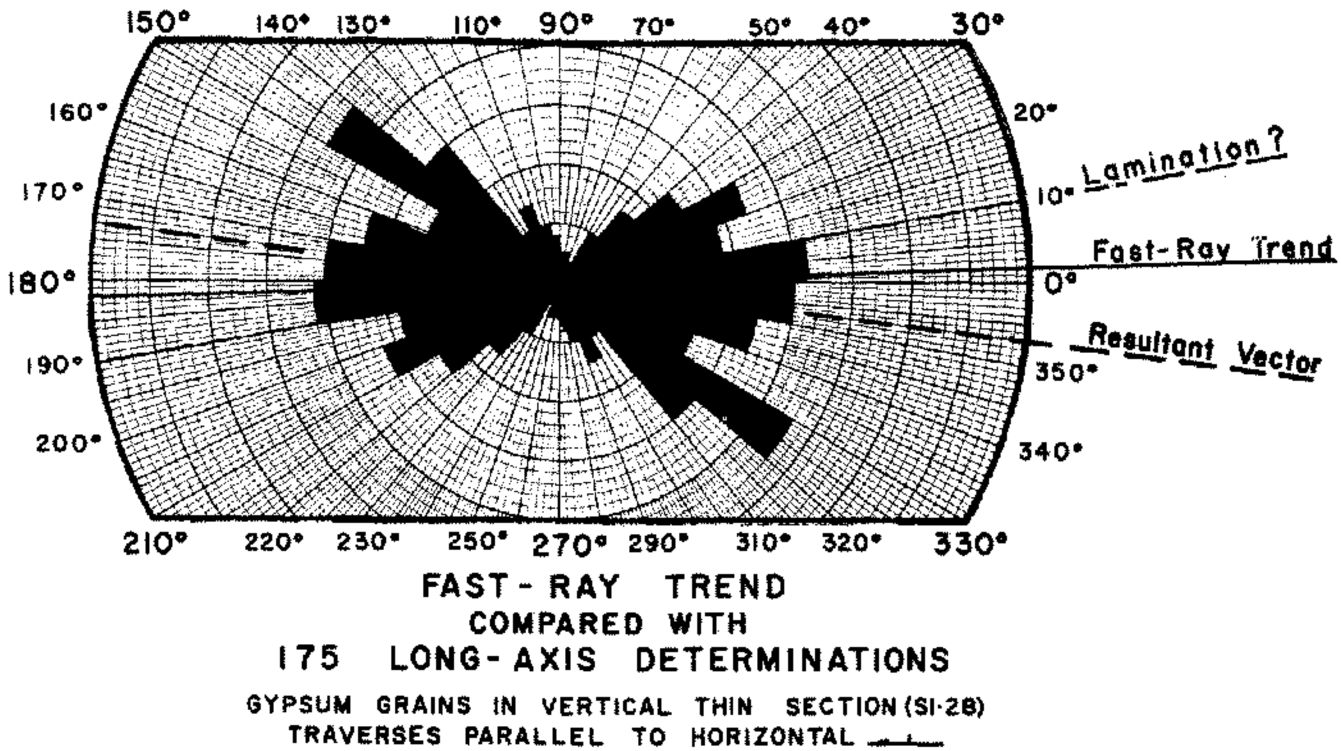

Figure 12. Comparison of fast-ray trend with direction of preferential shape orientation, lamination, and the horizontal for vertical section SI 28. Traverses parallel to horizontal.

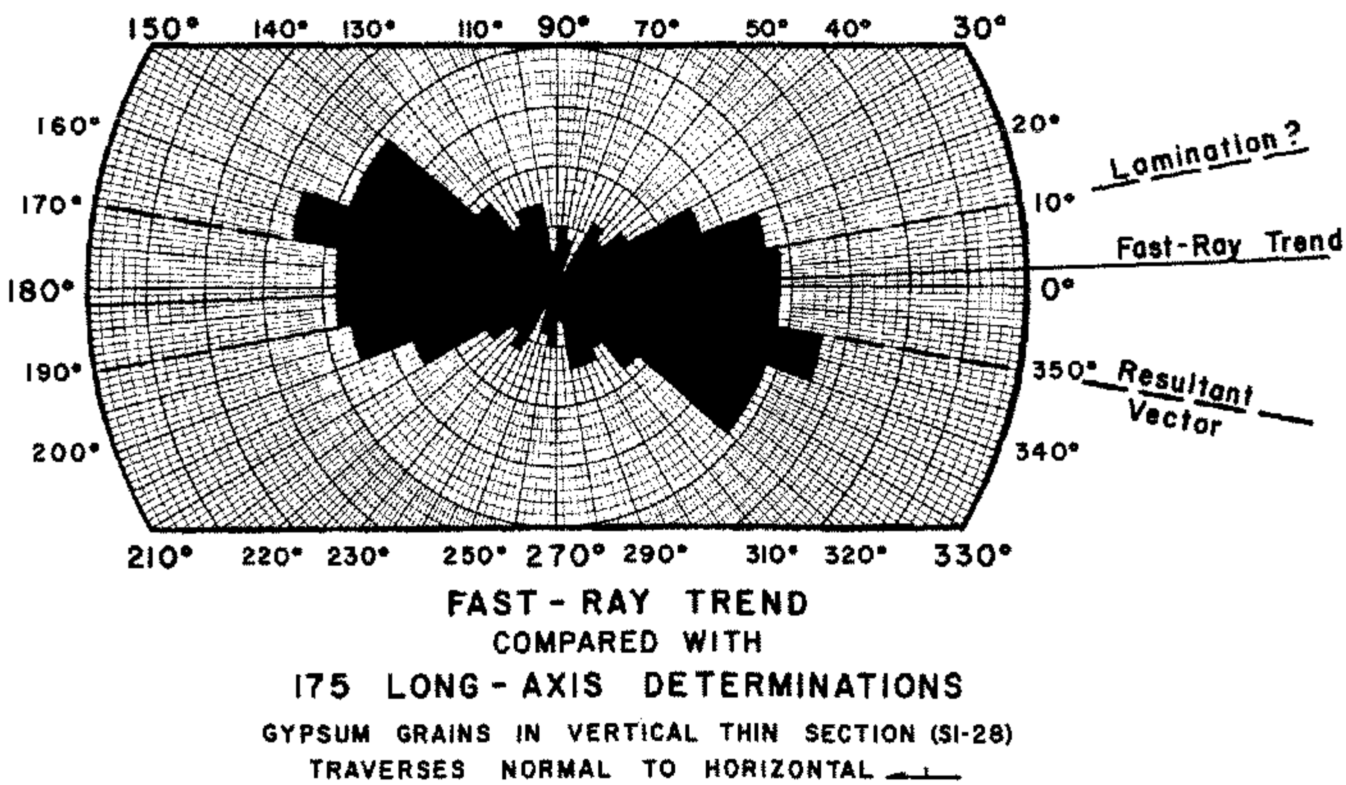

Figure 13. Comparison of fast-ray trend with direction of preferential shape orientation, lamination, and the horizontal for vertical section SI 28. Traverses normal to horizontal.

to (010) in gypsum. Thus some physical property other than (010) cleavage must be responsible for the observed relation. This observation may be of significance in studies of ancient deposits of detrital gypsum or of chemically deposited grains which have crystallized at some level above the surface of deposition.

The use of a settling tube to provide preferred orientation of non-equant grains and the statistical determination of an index of oblateness may have general application in the study of detrital sediments.

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