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# Statistical Anisotropy

**Introduction:** Anisotropy in rocks arises from the heterogeneous nature of mineral rocks. It refers to the direction-dependent variation of properties or parameters of interest within a considered formation. Here we shall narrow our consideration to rock samples and petroleum reservoirs. Such formations vary from given rock samples to petroleum reservoirs. Properties that usually exhibit anisotropic properties include, measured velocities, porosity and permeability.

Anisotropy in the properties of rock samples and in reservoirs presents a significant challenge for Earth Scientists. While Petroleum Engineers require information on rock anisotropy for analyzing borehole stability, reservoir production, hydraulic fracturing, and evaluating naturally fractured reservoirs, Geophysicists need information on anisotropy to accurately model seismic wave propagation in the subsurface.

There are various scales of anisotropy depending on the interest of the scientist. Various methods may be used to represent the anisotropic nature of the matter of interest all in an attempt to present the data in a logical manner. Here, anisotropic variation is viewed using the histogram.

**The Histogram:** For large data sets the histogram (fig. 1) makes a very good display of data distribution. According to Kreyszig (1999), the height of a rectangle of a histogram with class mark x is the relative class frequency defined as the number of data values in that class interval, divided by n (the total number of data values). Hence the areas of the rectangles are proportional to these relative frequencies, which make the histogram a good impression of the distribution of data.

**Scales of Anisotropy:** According to Briggs P. et. al., (1992), Reservoir heterogeneity can be considered in four scales, which are:

1. Micro (microns).
2. Macra (in, ft).
3. Mega (100-1000ft)
4. Giga (> 1000ft)

Formation properties obtained can be displayed at any of these scales by using the method discussed here.

**Parameters of Interest:** Parameters of interest include porosity, permeability, velocity distribution and any other measurable variable by which a formation can be characterized.

**Data Presentation:** In geophysical exploration, data presentation can be in various forms. Such include numerals and seismic session display. Various forms of charts and figures are also used, as well as statistical data displays.

In statistical data display, with respect to this write-up, the histogram is the method emphasized. For the purpose of this paper, the frequency of distribution and the class width are considered.

Statistical Representation of Anisotropy, Some Practical cases: First, consider a completely isotropic situation. This is shown in figure 2. It is seen that such can be represented by a single block in the histogram. The blocks of the histogram, with respect to the chosen class width defines the various elements of anisotropy for the considered measured variable. In fig 3, the class width is 0.25 (total number of data values for this as well as for figs. 4 and 5) and the number of classes is 16. In figure 4, the class width is 0.0625 (a reduction of that in fig 3 by four) and the number of classes is 64. In fig 5, the class width is 1.0 (an increase of that of figure 3 by a factor of four) and the number of classes is just 4. It can therefore be inferred that by decreasing the class width, the scale of anisotropy is reduced thereby specifying to greater details, (increase in the number of classes) the contributing anisotropic values. When the class width is increased, the number of classes reduces and the tendency is towards being isotropic. For the purpose of this paper, these three arbitrary class widths are labeled as "A", "B" and "C" scales respectively for figures 3, 4 and 5.

**Scales Limit:** As mentioned earlier as the scale is increased, the tendency is towards isotropy. However when the scale is reduced as shown in figures 4 and 5 with respect to the values in figure 3, there is a limit to such reduction after which no further changes will be observed. Further reduction will "wipe of the histogram".

**Conclusion:** It has been demonstrated that the histogram can be used for anisotropic data representation in formation properties. By varying the class width (which also varies the number of classes) for any given data set, the scale of anisotropy can be varied. The upper limit tends towards isotropy while the lower limit is reached when the variation of the class width no longer changes histogram. Further studies towards synchronizing it with the four scales of reservoir heterogeneity for the purpose of standardization continue.

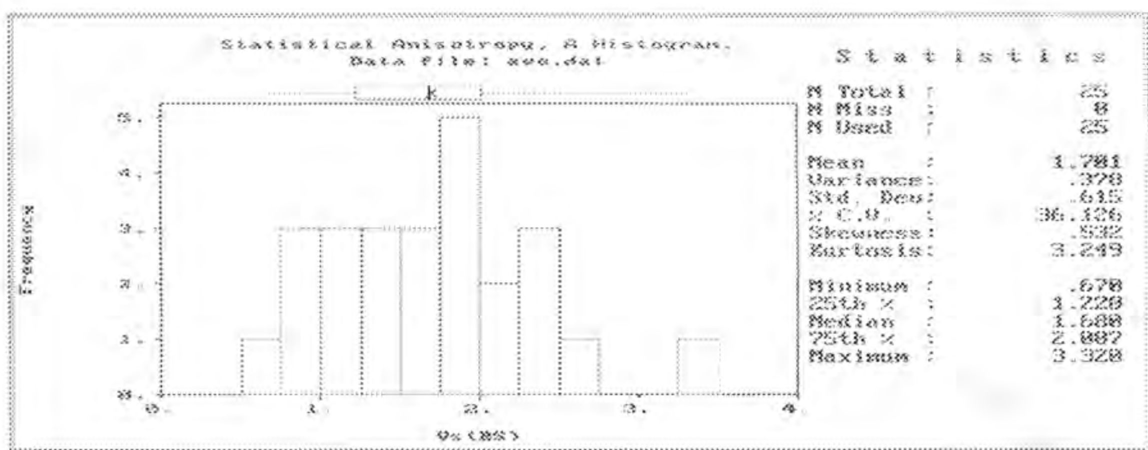


Fig. 1. The Histogram.

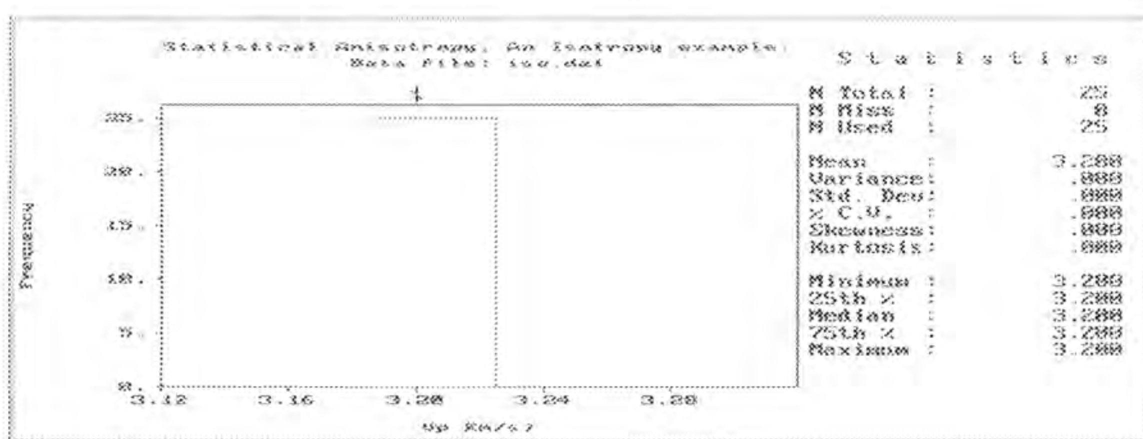


Fig. 2. An Isotropic Situation.

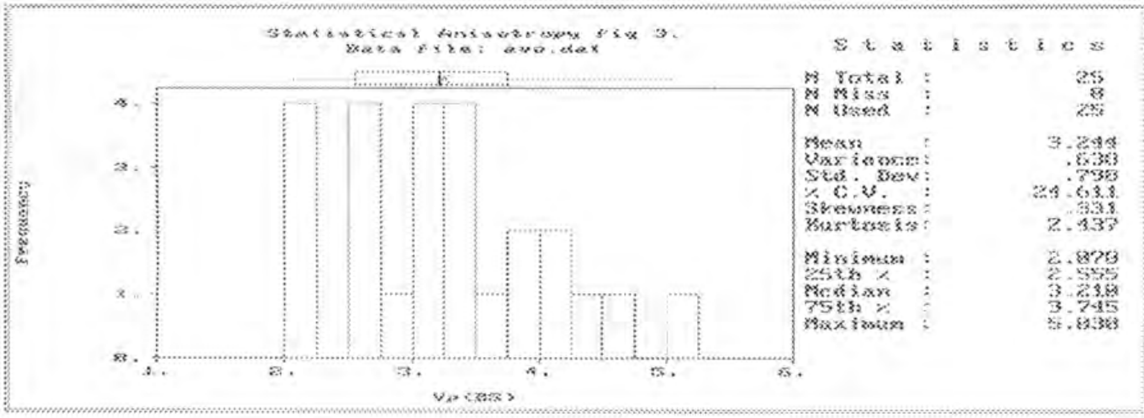


Fig. 3. A Scale of Anisotropy. ("A" scale).

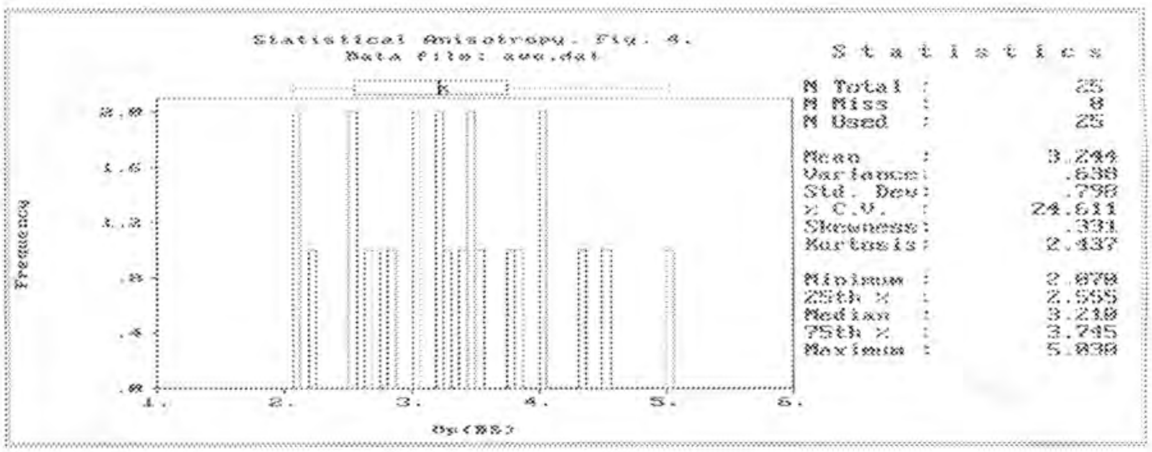


Fig. 4. A Scale of Anisotropy ("B" Scale).

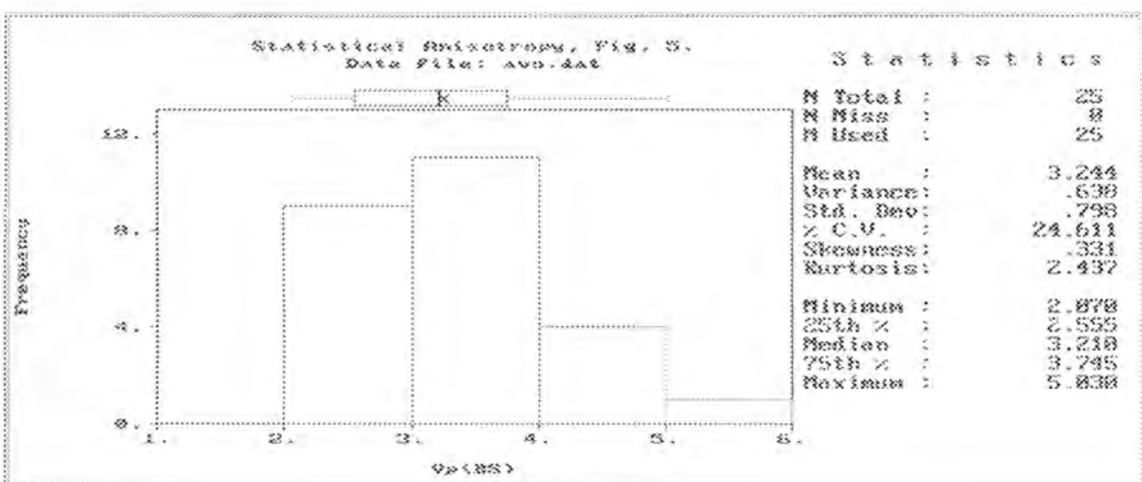


Fig. 5. A Scale of Anisotropy ("C" Scale).