EVALUATING THE EFFECTIVENESS OF FLINN'S K-VALUE VERSUS LODE'S RATIO

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ABSTRACT

Lode's ratio (ν) and Flinn's k-value are the most commonly used parameters for characterizing the shape of ellipsoids. Both parameters characterize this shape by utilizing ratios of the lengths of the principal axes. For oblate, plane strain, and prolate ellipsoids, there is an exact relationship between k and ν; however, this is not true for any other ellipsoid. In fact, as k approaches zero and infinity, the possible range in ν is 1.0, i.e., 50% of its total range. Correspondingly, as ν approaches zero from either the right or the left, the possible range in k is 50% of its total range.

Given the inherent differences between k and ν, we use synthetic datasets as a means of comparing the relative effectiveness of these two shape parameters in different strain regimes. Lode's ratio demonstrated a largely strain shape-independent set of standard deviations whereas the k-value datasets were significantly dependent on both strain shape and magnitude. Furthermore, the geometry of the confidence regions within the Flinn diagram are very much strain regime dependent, making it difficult to compare within datasets that have a range of k-values. In lieu of these results, we encourage investigators to more critically evaluate their choice of ellipsoid shape parameter.

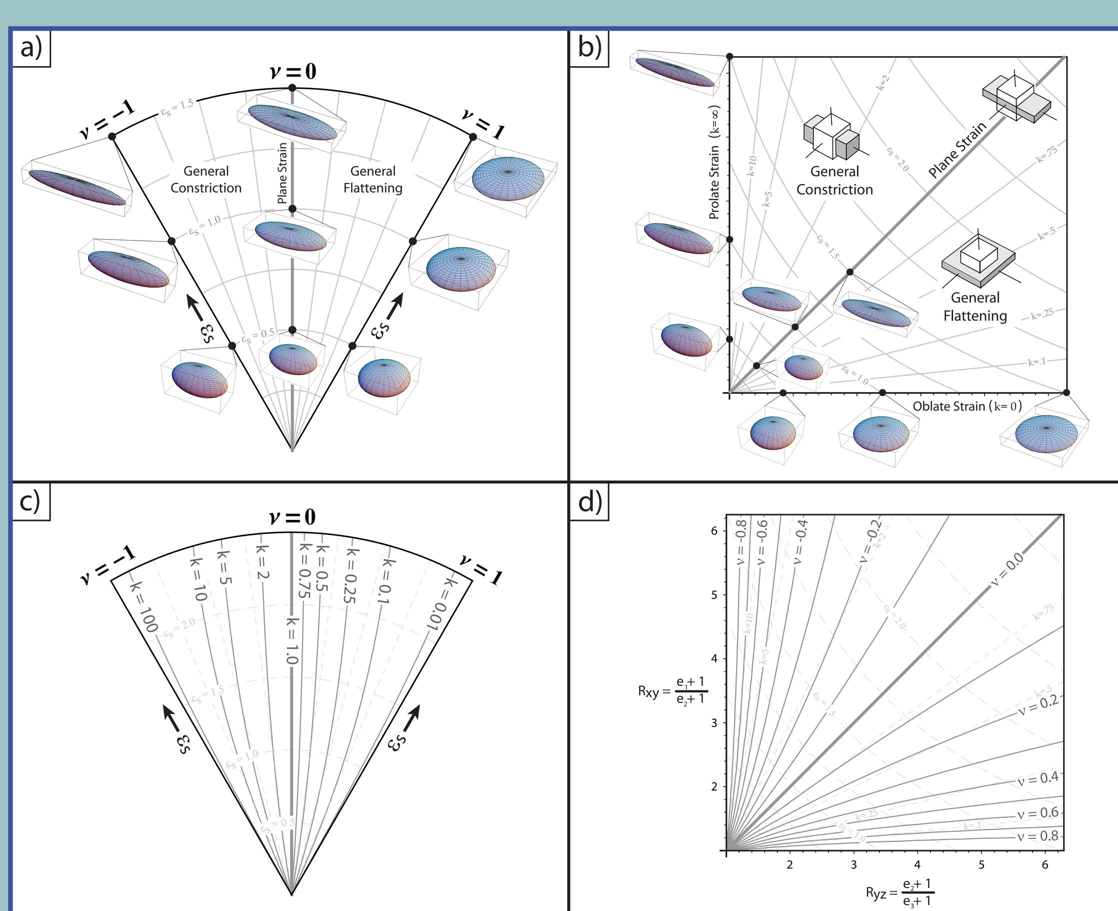

Figure 1. a) a typical Hsu diagram with representative strain ellipsoids, b) a Flinn diagram with k-value and octahedral shear strain (ε_s) contours shown with representative strain ellipsoids, c) a Hsu diagram with Flinn's k-values contoured, and d) a Flinn diagram with Lode's ratio contours.

Octahedral shear strain (ε_s) contours in Flinn space are calculated using the following formula:

$$y = e^{\frac{1}{2}\left(\mathrm{Ln}\left[\frac{1}{x}\right] + \sqrt{3}\sqrt{2\,\varepsilon_s^2 - \mathrm{Ln}\left[\frac{1}{x}\right]^2}\right)}$$

where x has a range from 1 to $e^{\sqrt{\frac{3}{2}}\varepsilon_s}$

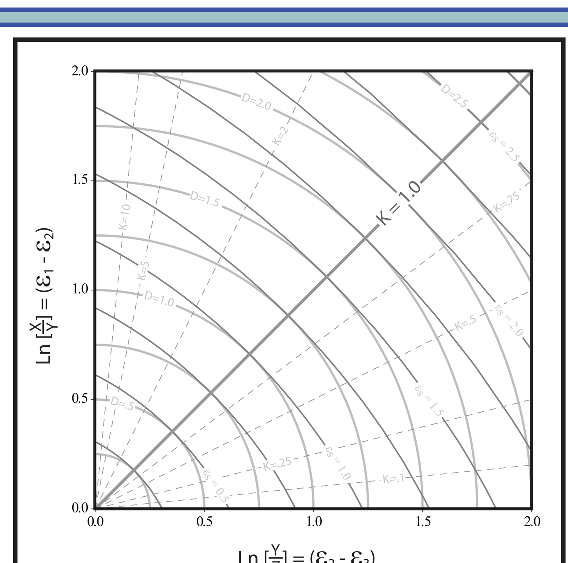

Figure 2. A logarithmic Flinn diagram/Ramsay diagram illustrating Ramsay and Huber's (1983) D- and K-value contours along with octahedral shear strain (ε_s) contours.

Flinn's k-value versus Lode's ratio

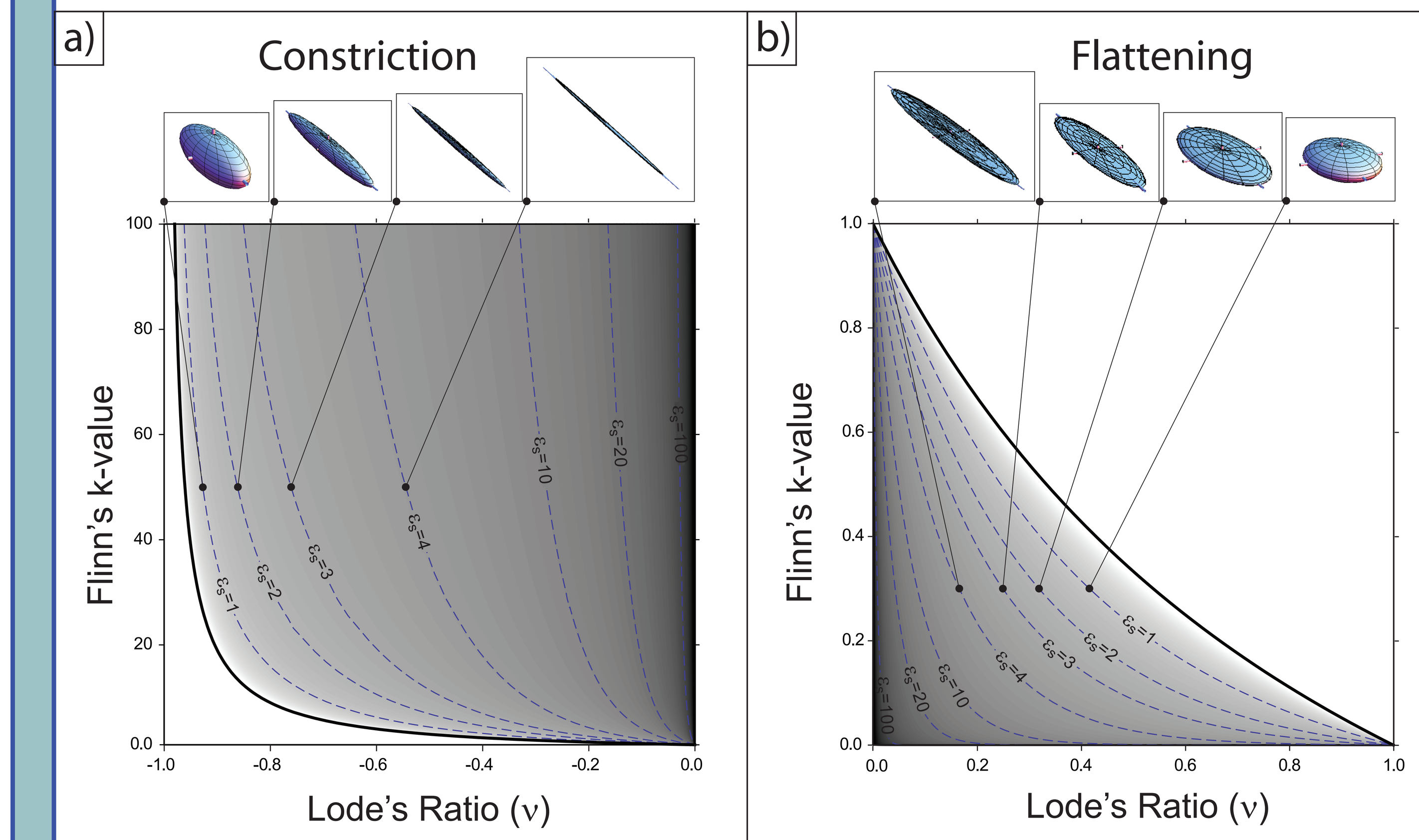

Figure 3. An illustration of the relationship between Flinn's k-value, Lode's ratio (ν), and octahedral shear strain (ε_s), for a) constrictional strain geometries, and b) flattening strain geometries.

To generate Figures 3 and 4, k was solved for in terms of Lode's ratio (ν), and octahedral shear strain (ε_s):

$$k(\nu,\varepsilon_s) = \frac{1-e^{\left(-\frac{\sqrt{\frac{3}{2}}\,\varepsilon_s(-1-\nu)}{\sqrt{3-\nu^2}}\right)}}{1-e^{\left(\frac{\sqrt{\frac{3}{2}}\,\varepsilon_s(1+\nu)}{\sqrt{3+\nu^2}}\right)}}$$

Flinn's k-value versus Lode's ratio

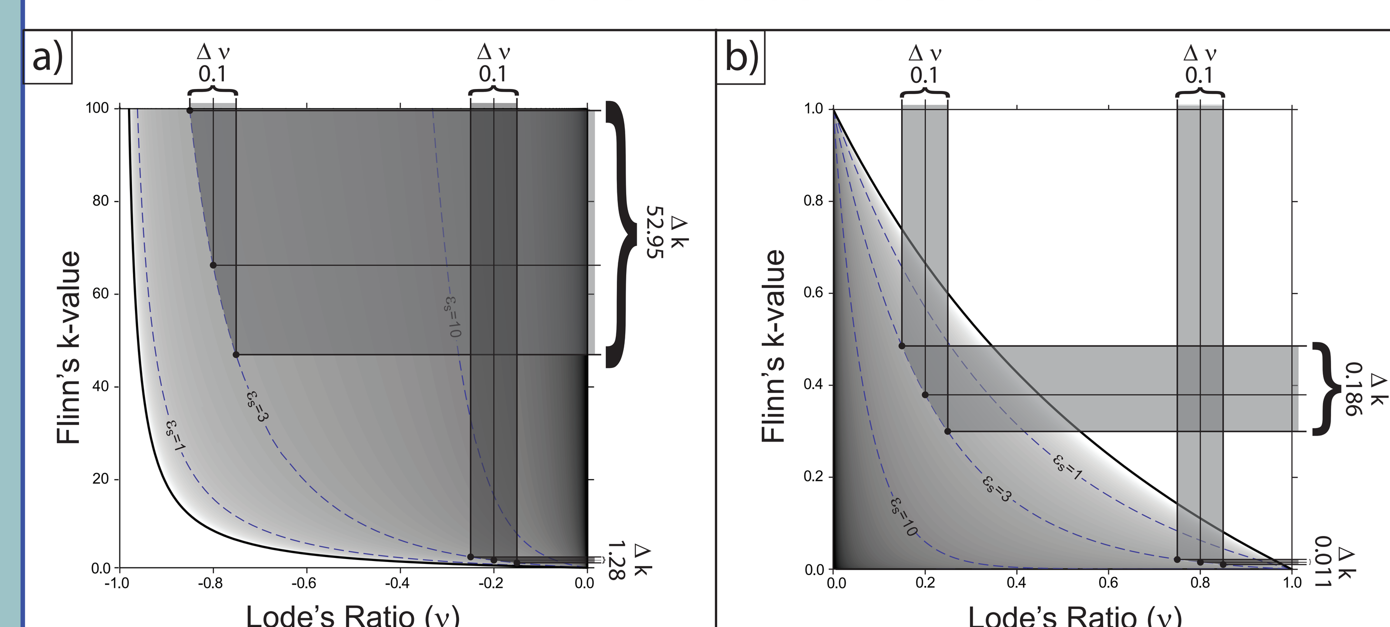

Figure 4. An illustration of how uncertainty in Lode's ratio (Δν), specifically ±0.05, translates into uncertainty in Flinn's k-value (Δk) for an octahedral shear strain (ε_s) of 3 for a) constrictional strain geometries, and b) flattening strain geometries.

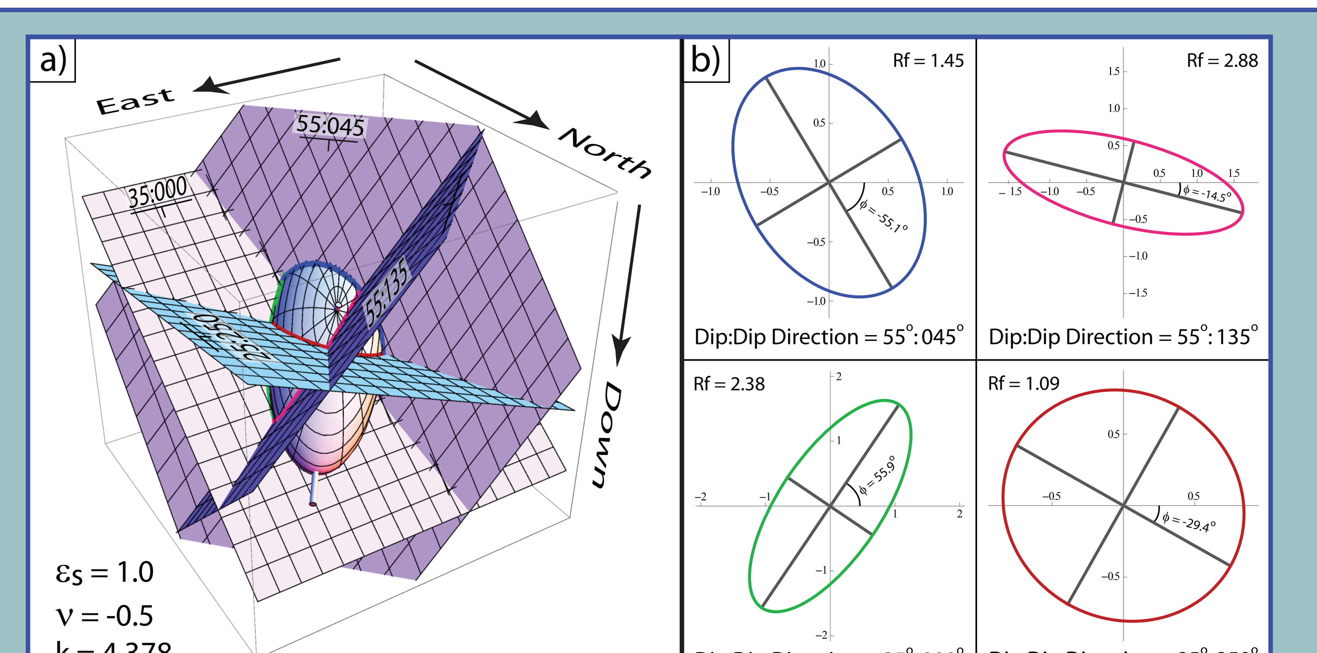

Figure 5. Sectional data from a seed ellipsoid generated by the program "Sectional Data through an Ellipsoid.nb" from the "Geological Programs for Mathematica" software suite (Mookerjee & Nickleach, 2011). a) the sectional plane orientations used to generate the synthetic datasets cutting through an example ellipsoid with an octahedral shear strain (ε_s) = 1, Lode's ratio (ν) = -0.5, and Flinn's k-value = 4.378, b) elliptical sections from the example ellipsoid from which the synthetic data (axial ratios (Rf) and angular orientations (ϕ)) are derived.

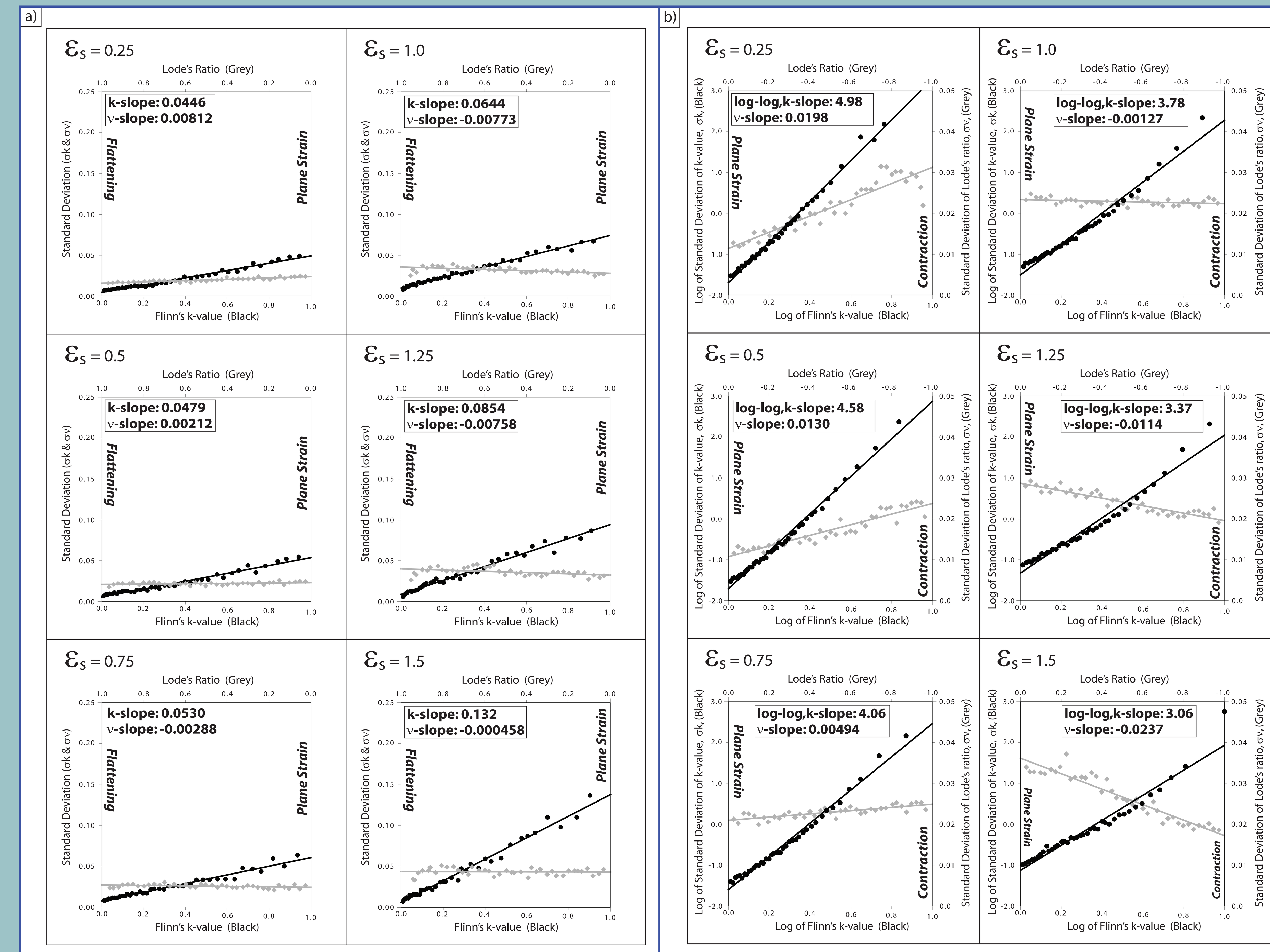

Figure 6. a) Standard deviations of Lode's ratio (σν) and Flinn's k-value (σk) plotted against the corresponding value of general flattening Lode's ratio (ν) and Flinn's k-value for given octahedral shear strains (ε_s). The standard deviations are all calculated from synthetic datasets of one hundred ellipsoids, b) Standard deviations of Lode's ratio (σν) and Flinn's k-value (σk) plotted against the corresponding value of general constriction Lode's ratio (ν) and Flinn's k-value for given octahedral shear strains (ε_s).

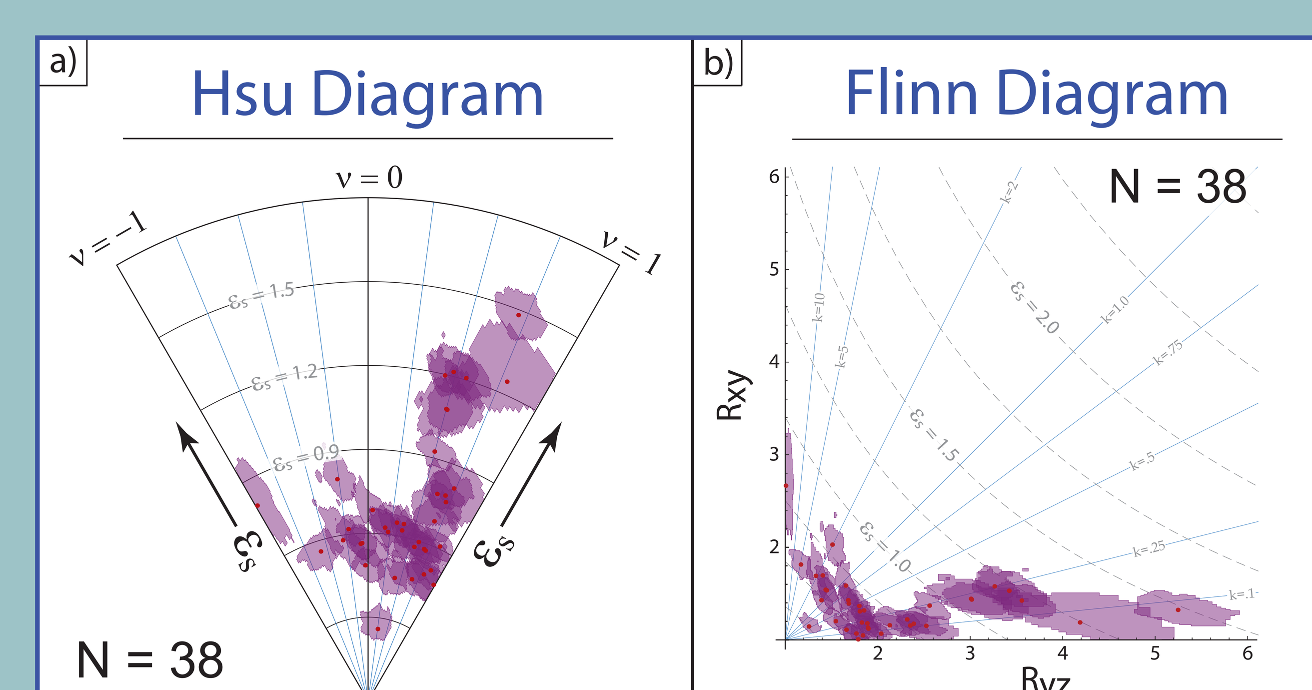

Figure 7. Three-dimensional strain data from the deformed footwall quartzites beneath the Moine Thrust, NW Scotland (Mookerjee & Mitra, 2009). The shaded regions surrounding each data point represents the 95% confidence area using the statistical methods described in Mookerjee & Nickleach (2011). a) Hsu diagram, and b) Flinn diagram.

CONCLUSION

Three-dimensional strain analysis is a crucial part of structural geology. In order to effectively discuss 3D strain datasets we need parameters that can characterize the amount of distortion (i.e., strain magnitude) of the strain ellipsoid, as well as the strain shape. Both Lode's ratio and Flinn's k-value have been utilized, to good effect, in characterizing strain shape. However, the choice of shape parameter is typically under-evaluated. To investigate this issue of the effectiveness of these two strain shape parameters, we determined a precise functional relationship between k, ν, and ε_s, and analyzed synthetically-derived strain datasets over a variety of strain regimes. Because the standard deviations of Lode's ratio were far more consistent than the corresponding standard deviations of Flinn's k-value within these analyses, we suggest that ν is the more effective strain shape parameter for kinematic analyses in which there is a range of strain geometries. This is not to say that ν is always the best strain shape parameter, just the most consistent. Moreover, the Hsu diagram more consistently represents the confidence regions, within the strain geometry space, for all strain regimes. We hope that the above analysis gives investigators the tools necessary to more easily make informed decisions about which parameter best suites their specific needs.