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Characterization and scaling of anisotropy of fabrics and fractures at laboratory scales: insights from volumetric analysis using computed tomography

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Anisotropy in three-dimensional quantities such as geometric shape and orientation is commonly quantified using principal components analysis, in which a second order tensor determines the orientations of orthogonal components and their relative magnitudes. This approach has many advantages, such as simplicity and ability to accommodate many forms of data, and resilience to data sparsity. However, when data are sufficiently plentiful and precise, they sometimes show that aspects of the principal components approach are oversimplifications that may affect how the data are interpreted or extrapolated for mathematical or physical modeling. High-resolution X-ray computed tomography (CT) can effectively extract thousands of measurements from a single sample, providing a data density sufficient to examine the ways in which anisotropy on the hand-sample scale and smaller can be quantified, and the extent to which the ways the data are simplified are faithful to the underlying distributions. Features within CT data can be considered as discrete objects or continuum fabrics; the latter can be characterized using a variety of metrics, such as the most commonly used mean intercept length, and also the more specialized star length and star volume distributions. Each method posits a different scaling among components that affects the measured degree of anisotropy. The star volume distribution is the most sensitive to anisotropy, and commonly distinguishes strong fabric components that are not orthogonal. Although these data are well-presented using a stereoplot, 3D rose diagrams are another visualization option that can often help identify these components. This talk presents examples from a number of cases, starting with trabecular bone and extending to geological features such as fractures and brittle and ductile fabrics, in which non-orthogonal principal components identified using CT provide some insight into the origin of the underlying structures, and how they should be interpreted and potentially up-scaled.