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Compactant strain localization in an anisotropic sandstone inferred from X-ray CT imaging

L. Louis (1), P. Baud (2), S. Tembe (1), T.-f. Wong (1)

(1) Department of Geosciences, SUNY at Stony Brook, USA (llouis@notes.cc.sunysb.edu),
(2) Institut de Physique du Globe, EOST (CNRS/ULP), Strasbourg, France
(pbaud@eost.u-strasbg.fr)

Strain localization refers to the appearance of a local discontinuity in the velocity gradient across a surface bounding a zone undergoing deformation while the surrounding volume remains intact. Localization may be associated with positive or negative volume change, depending on whether the material is experiencing brittle failure or shear enhanced compaction. Density values and strain gradients can be mapped out non-destructively using X-ray CT imaging, application that was introduced in the early 80's. To date, most studies have focused on dilating zones in which a local increase in porosity results in considerable decrease in attenuation. In this work, we studied density contrasts arising from localization in the compactive regime and its dependence on load axis orientation in an anisotropic sandstone through X-ray tomography and radiography.

One of our Diemelstadt sandstone samples was triaxially compressed at 150MPa pressure. Once deformed, several compaction bands oriented subperpendicular to the maximum principal stress were visible on its exterior surface. To get a 3D picture of these features we acquired a series of CT slices, which exhibited a very slight attenuation contrast between grain inside and outside the zones of localization. To enhance this contrast, we calculated local average density gradients (volumetric strain gradients) between each pixel and its 26 nearest neighbors, based on the hypothesis that zones of localized deformation should display anomalously low gradients due to a more homogenized porosity. The resulting images display thin planar structures of about .7 mm, which seem to have propagated from the exterior surface into the interior of the sample. In order to investigate the effect of an intrinsic anisotropy on the microstructural development of compaction, a strongly laminated sandstone (Rothbach)

was tested at similar pressure conditions (130MPa). We triaxially deformed three samples cored along different orientations (0, 45 and 90 degrees) relative to the bedding plane. X-ray digital radiographs were acquired before and after shortening. While sedimentary laminae were clearly visible in all images, no localized compaction pattern clearly emerged in the radiographs of the deformed samples. A correlation-based calculation was performed in order to resolve small local displacements after deformation. The resulting images showed that the three samples achieved overall shortening in different manners: the sample cored perpendicular to the bedding (P) plane exhibited a few sharply localized zones of compaction, while the same amount of shortening was distributed through the entire sample cored parallel to the bedding plane (H). Our results on the sample P were compared to crack density mapped on a thin section using optical microscopy and a classical stereological technique.