Some thoughts on jointing.

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Although the fracture mechanics of solids is a well-developed theory, the theory behind the formation of joint systems has not been developed at all, at least not to the extent that it is well accepted. It would seem to us that a major step towards a unified theory of joint formation was made by the papers by Veveakis and Regenauer-Lieb (2015), Alevizos et al. (2017) and Veveakis and Poulet (2021). These papers present a theory for the viscoplastic deformation of porous solids that demonstrates the formation of discontinuities that are singularities in porosity of pore fluid pressure. These singularities form along the characteristics of the deformation field and correspond to fractures, compaction bands, shear zones or extension fractures depending on the loading conditions and constitutive relations. The first two of the above papers are for 1-dimensional situations whereas the third paper is an attempt to extend theory to 2-dimensions. It is unfortunate that the authors of paper 3 chose to represent the theory as an application to mud-cracks when the theory is just as applicable to solids. It is also unfortunate that the authors of paper 3 chose to develop a treatment that involves only biaxial extension. In looking at the theory it seems to us that the theory should be just as applicable to biaxial compression when the discontinuities would be compaction bands.

The theory as developed by Veveakis and Poulet (2021) suggests that two types of deformation discontinuity patters might develop in 2-dimensions (Figure 1). One is a hexagonal pattern and the other a square pattern. Of these the hexagonal pattern has the lowest surface energy followed closely by the square pattern. The one that develops is governed by local heterogeneities but it is observed that Nature choses the square pattern in most cases. A splendid example that follows closely the Veveakis and Poulet (2021) treatment is Figure 2. We believe that similar square patterns can be developed in biaxial compression and this type represents the common patterns seen in Nature (Figure 3).

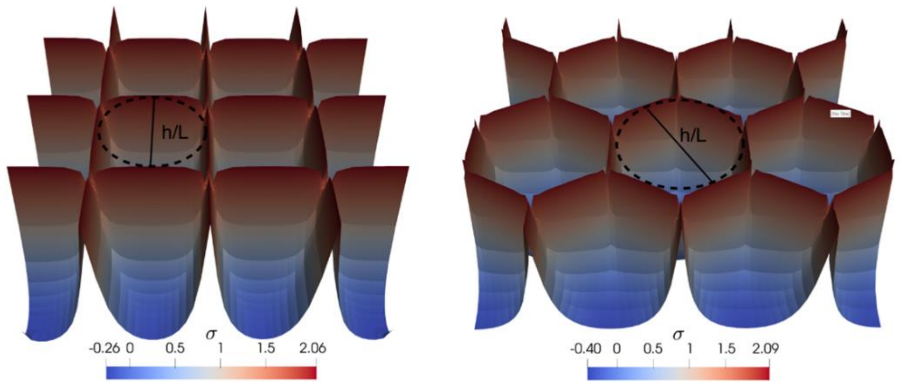

Figure 5: Numerical solution of the 2D Eq. 7 for $m = 3$ and $\lambda = 200$, using the finite element code REDBACK[10] with symmetry conditions at the sides of the square domain and Dirichlet boundary conditions at the corners. (left) Square patterns of stress peaks/cracks are forming, when the initial condition is perturbed using square pattern with a 0.1 % stress perturbation. (right) Hexagonal patterns of stress peaks/cracks are forming, when the initial condition is perturbed using hexagonal pattern with a 0.1 % stress perturbation. In both cases, the patterns are inscribing a circle of diameter h/L, obeying the spacing of Eq. 10.

From Veveakis M., Poulet, T. A note on the instability and pattern formation of shrinkage cracks in viscoplastic soils.

Figure 1. The two probable patterns of failure discontinuities predicted by Veveakis and Poulet (2021). The hexagonal pattern has the lowest surface area but is followed closely by the orthogonal pattern.

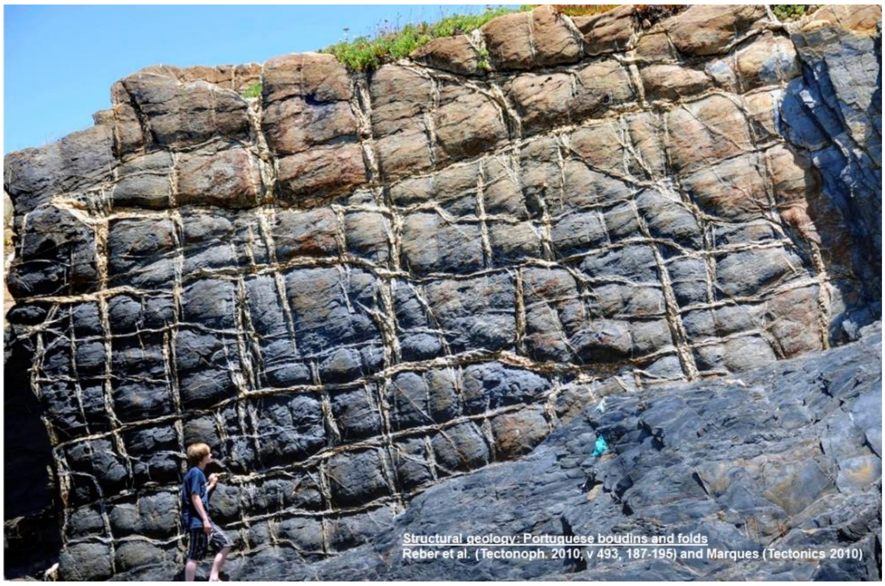

Figure 2. Orthogonal extension veins formed in biaxial extension. Portugal.

Figure 3. Two views of orthogonal joint systems Ormiston Gorge, NT.

However. Although the lowest energy configuration predicted by Veveakis and Poulet (2021) is rare, it apparently does exist in the examples shown by Zoltán Sylvester, 2023 and repeated in Figures 4 – 7.

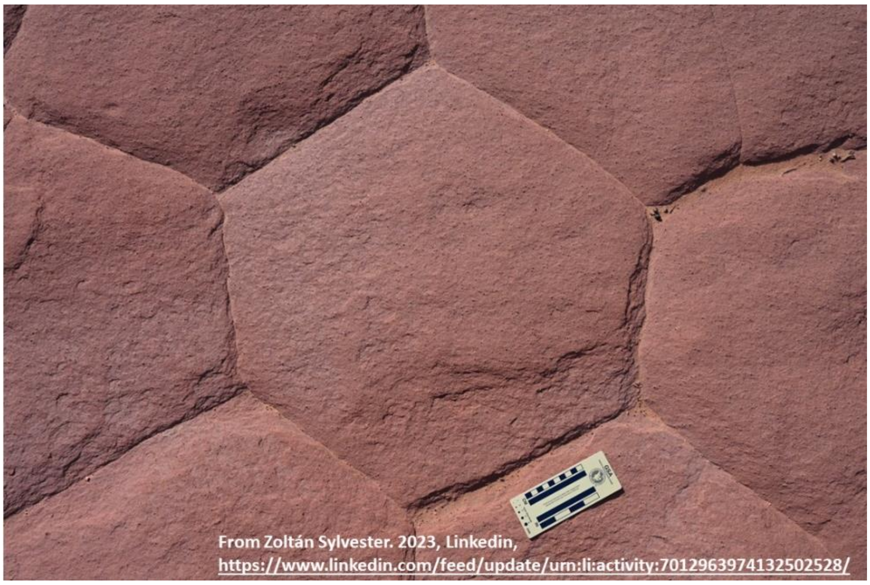

Figure 4. Hexagonal joint system in Aztec sandstone.

Figure 5. Hexagonal joint system in Aztec sandstone grading locally into orthogonal or pentagonal patterns.

Google Earth. Kane County, Utah, USA. 37°02'43.0"N 111°59'37.0"W

Figure 6. Satellite view of hexagonal joint system in Aztec sandstone grading locally from hexagonal into orthogonal or pentagonal patterns. Notice that finer scale systems exsit within the main system sugesting that the energy potential that is minimised to form these patterns is non-convex.

The conclusion is that the features described by Zoltán Sylvester, 2023. Are joint patterns formed in biaxial compression by the coupled processes described by Veveakis and Poulet (2021). The hexagonal patterns represent the lowest energy configuration, but the orthogonal pattern is very close to minimum energy also. The presence of fine scale structure within the main structure suggests the energy potential that is minimised is non-convex. It would be interesting to see if any of these fractures are compaction bands, common elsewhere in the Aztec sandstone.

Figure 7. Satellite view of joint system in Aztec sandstone grading locally from hexagonal into orthogonal, pentagonal and linear patterns. Notice that finer scale systems exsit within the main system sugesting that the energy potential that is minimised to form these patterns is non-convex.

References

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