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# Modelling and interpreting biologically crusted dryland soil sub-surface structure using automated micropenetrometry

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Soil penetrometers are used routinely to determine the shear strength of soils and deformable sediments both at the surface and throughout a depth profile in disciplines as diverse as soil science, agriculture, geoengineering and alpine avalanche-safety (e.g. Grunwald et al. 2001, Van Herwijnen et al. 2009). Generically, penetrometers comprise two principal components: An advancing probe, and a transducer; the latter to measure the pressure or force required to cause the probe to penetrate or advance through the soil or sediment. The force transducer employed to determine the pressure can range, for example, from a simple mechanical spring gauge to an automatically data-logged electronic transducer. Automated computer control of the penetrometer step size and probe advance rate enables precise measurements to be made down to a resolution of 10's of microns, (e.g. the automated electronic micropenetrometer (EMP) described by Drahorad 2012).

Here we discuss the determination, modelling and interpretation of biologically crusted dryland soil sub-surface structures using automated micropenetrometry. We outline a model enabling the interpretation of depth dependent penetration resistance (PR) profiles and their spatial differentials using the model equations,

$$\sigma(z) = \sigma_{c0}+\Sigma_1^n[\sigma_n(z) + \mathrm{a}_n z + b_n z^2]$$

and

$$d\sigma\ /dz = \Sigma_1^n[\mathrm{d}\sigma_n(z)/dz\ + \mathrm{F}_{rn}(z)]$$

where $\sigma_{c0}$ and $\sigma_n$ are the plastic deformation stresses for the surface and $n^{th}$ soil structure (e.g. soil crust, layer, horizon or void) respectively, and $F_{rn}(z)dz$ is the frictional work done per unit volume by sliding the penetrometer rod an incremental distance, *dz,* through the $n^{th}$ layer. Both $\sigma_n(z)$ and $F_{rn}(z)$ are related to soil structure. They determine the form of $\sigma(z)$ measured by the EMP transducer. The model enables pores (regions of zero deformation stress) to be distinguished from changes in layer structure or probe friction.

We have applied this method to both artificial calibration soils in the laboratory, and *in-situ* field studies. In particular, we discuss the nature and detection of surface and buried (fossil) subsurface Biological Soil Crusts (BSCs), voids, macroscopic particles and compositional layers. The strength of surface BSCs and the occurrence of buried BSCs and layers has been detected at sub millimetre scales to depths of 40mm. Our measurements and field observations of PR show the importance of morphological layering to overall BSC functions (Felde et al. 2015).

We also discuss the effect of penetrometer shaft and probe-tip profiles upon the theoretical and experimental curves, EMP resolution and reproducibility, demonstrating how the model enables voids, buried biological soil crusts, exotic particles, soil horizons and layers to be distinguished one from another. This represents a potentially important contribution to advancing understanding of the relationship between BSCs and dryland soil structure.

**References:**

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