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Using additive manufacturing to make 3D porous ceramic microcosms to study soil processes

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Our understanding of soil processes is limited by our ability to perform reproducible experiments and interrogate them at the pore scale, where micro-habitats enable the diversity of processes in soil. Our goal is to make microcosm devices that replicate pore-scale characteristics of soil, enabling studies that can provide new insights into carbon cycling in soil and ultimately be used to parameterize pore-scale computer models (Fig. 1). Our approach is to use additive manufacturing methods to make hierarchical porous structures that can be manipulated to replicate micro-habitat properties, such as wetting and drying, solute transport, and microbial growth. We are experimenting with making these microcosms with material such as silica, alumina, and kaolin that can be cast or printed and sintered to make porous ceramic experimental devices that can be non-destructively interrogated. We are varying particle size, carrier, polymer fillers and forms, and manufacturing conditions to control internal structure. We will amend the devices with coatings and clays to replicate the pore-scale characteristics of soil. We are quantifying transport properties in and on these materials with optical methods using both low molecular weight fluorophores (rhodamine B, red) and microbial-sized fluorescent tracer particles (1 micron diameter microspheres, green). The results will provide insights not only on how nutrients and waste will flow through these systems, but also how microbial motility will be affected by the physical barriers imparted by these porous materials. We are also testing material biocompatibility and ability to deliver nutrients to microbes with plate experiments. For our modeling, we are developing 3D numerical models that can replicate the physical characteristics of the microcosms down to the pore scale. Our goal is to model multi-phase flow with geochemistry and biology. By developing microcosms whose characteristics are well-defined down to the pore scale, we anticipate being able to use the resulting experimental data to gain predictive power for pore-scale processes.

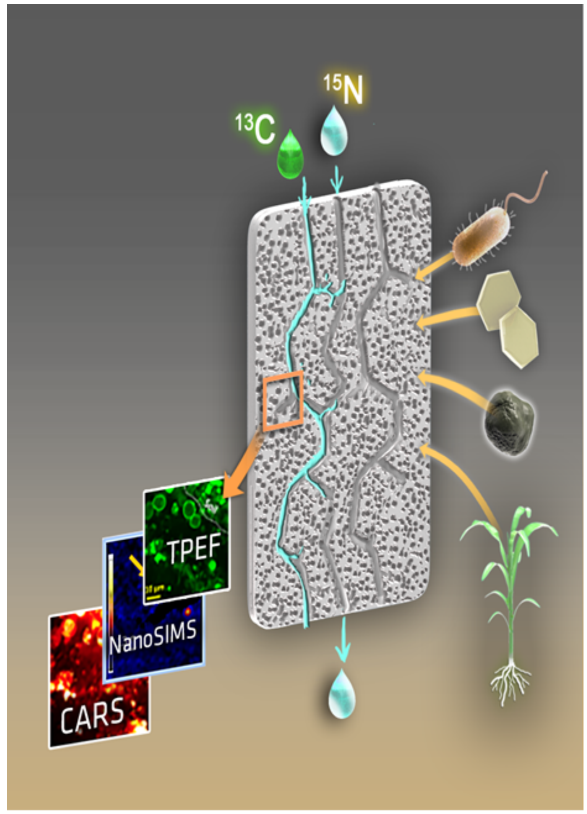

Fig. 1. Cartoon of our porous ceramic microcosm concept. The device could be amended with microbes, clays, organic matter and litter, provided water, nutrients and synthetic root exudates, and imaged during and after tracer and growth experiments.