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Quantification of soil heterogeneity induced by corroding metal objects, using X-ray computed micro tomography (CMT)

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Metal objects in soil, such as pipelines and sheet pile walls are subject to corrosion, that causes extensive economic damage - the annual direct costs of metal corrosion are estimated as 3-4% of the gross domestic product (GDP) of both developed and developing countries. Corrosion of the metal object results in the diffusion of corrosion products away from the original metal surface, where the corrosion products combine with dissolved species and precipitate, altering the properties of the porous medium. The result is a system composed of the uncorroded metal, the Dense Product Layer (DPL) composed of iron corrosion products, the Transformed Medium (TM) which is a mix of the corrosion products and compounds coming from the surrounding soil and the unaltered soil. Naturally occurring DPL's were reported to reduce the corrosion rate of metal objects in soil and studies of metal archaeological artifacts show that it is possible that microbiota plays a role in the process, controlling the rate and location of reprecipitation of corrosion products. However, the dynamics of such complex processes in soil are not yet fully understood and experimental results that can be used to calibrate and verify numerical models of corrosion processes in porous media are scarce. In this study, we explore the potential of X-ray computed microtomography (CMT) in quantifying the changes occurring in soil around corroding metal objects. Metal coupons were incubated in sand and scanned using a Phoenix Nanotom® s nanofocus computed tomography system. Using objects of known density in the samples, the measurements were density-calibrated and the increase in density and accompanying reduction in porosity due to reprecipitation of corrosion products were quantified. Our results demonstrate the potential of X-ray tomography in non-destructive quantification of corrosion processes in porous media. We suggest using smaller samples to increase resolution of the measurements and to use standardized density calibration phantoms to increase the compatibility of analysis and reliability of the density calibrations (such calibration phantoms still need to be developed though). Application of nano-tomography can provide time-lapse information about the density and porosity of the DPL and the TM during their development. Such information can significantly improve our understanding of bioinfluenced mineralization processes in porous media. Understanding these processes will allow us to utilize them in maximizing the protectiveness of naturally occurring coatings on metal infrastructure in soil, as a first step in developing the capacity to use Nature's constructive forces in assembling functioning structures.