Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35046

Reactive transport in the vadose zone - Progress, challenges and opportunities

K. ULRICH MAYER

University of British Columbia

The vadose zone is an important component of the critical zone, characterized by a high degree of complexity, both in terms of physical and biogeochemical processes. It consists of soils, subsoils, and underlying unsaturated sediments, and provides both a linkage and a buffer between the ground surface and groundwater. Over the past decades, multicomponent reactive transport modeling capabilities for the vadose zone have increased substantially. The resulting models have been instrumental for the development of an improved understanding of biogeochemical processes in soils and in the unsaturated zone. Gas transport processes have proven to be of key importance, both in natural and anthropogenically influenced systems. The ingress of atmospheric oxygen is of key importance in shaping vadose zone processes, with impacts on soil respiration, GHG cycling, attenuation of organic contaminants, fugitive gas emissions, and mine waste management. In addition, the vadose zone can provide a pathway for CO_2 capture from the atmosphere and the emission of organic vapors and radon from the subsurface. In this presentation, I will provide several examples to illustrate vadose zone reactive transport processes with an emphasis of gas dynamics, emphasizing similarities and differences between various applications. Despite substantial recent progress, there remain many challenges in capturing vadose zone reactive transport processes. These challenges include the role of preferential flow and transport in soils and the deep vadose zone, the presence of anoxic micro-environments in an otherwise oxic soil matrix, and the entrapment of soil gases due to water table fluctuations and transient recharge events, providing many opportunities for future work. Present-day RTMs constitute a development over many years, if not decades. The resulting codes are versatile and suitable to tackle a wide range of reactive transport problems. However, with capability comes complexity, which does provide challenges for future code developments, verification, and maintenance. Many existing codes are based on programming languages such as Fortran90 or C++, which may also impact future developments and progress. The advent of machine learning and AI is expected to provide additional tools to expand and build on existing RTM capabilities.