

Simulation of early karstification by synergistic mixing corrosion and retrograde solubility in carbonate reservoirs Postprint

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Abstract

The mixing of groundwater with varying carbon dioxide content and temperature plays a crucial role in karst evolution in carbonate reservoirs, driving both mixing corrosion and retrograde solubility. Research on karst evolution has primarily focused on independent mixing corrosion (MC), while the synergistic effect of mixing corrosion and retrograde solubility (MR) has received limited attention. This study employs a previously developed hydro-thermal-chemical coupled model to analyze the early karstification of a limestone basin system recharged by meteoric and cross-formational waters, varying in $P(\text{CO}_2)$, Ca^{2+} concentrations, and temperatures. The model incorporates structural heterogeneity and inflow aggressiveness to simulate two scenarios: MC and MR, for comparison. The results show that MC is more likely to occur in shallow aquifers, promoting preferential pathways along the water table. In contrast, MR not only accelerates dissolution at the water table but also increases flow fluxes and the extent of karstification at greater depths. As the decreasing aggressiveness of meteoric water weakens the nonlinear kinetics of dissolution, the duration of early karstification by MC is significantly longer than that of MR. In the shorter karst evolution process driven by MR, increased flow fluxes and conduit diameters at greater depths facilitate the development of longer vertical permeable tunnels along the faults, while hindering conduit enlargement at the water table. These findings reveal distinct modes of karstification for MC and MR, highlighting the significant role of thermal and chemical heterogeneity in karst evolution. This study provides deeper insights into carbonate reservoirs and offers practical implications for improving the efficiency of hydrothermal resource exploitation and geological CO_2 storage.

Full Text

Preamble

Simulation of Early Karstification by Synergistic Mixing Corrosion and Retrograde Solubility in Carbonate Reservoirs

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Abstract

The mixing of groundwater with varying carbon dioxide content and temperature plays a crucial role in karst evolution in carbonate reservoirs, driving both mixing corrosion and retrograde solubility. While previous research on karst evolution has primarily focused on independent mixing corrosion (MC), the synergistic effect of mixing corrosion and retrograde solubility (MR) has received limited attention. This study employs a previously developed hydro-thermal-chemical coupled model to analyze the early karstification of a limestone basin system recharged by meteoric and cross-formational waters that vary in $P(\text{CO}_2)$, Ca^{2+} concentrations, and temperatures. The model incorporates structural heterogeneity and inflow aggressiveness to simulate two scenarios—MC and MR—for comparative analysis.

The results demonstrate that MC predominantly occurs in shallow aquifers, promoting the development of preferential flow pathways along the water table. In contrast, MR not only accelerates dissolution at the water table but also enhances flow fluxes and extends the degree of karstification at greater depths. As the aggressiveness of meteoric water decreases, it weakens the nonlinear dissolution kinetics, causing the duration of early karstification driven by MC to be significantly longer than that of MR. In the shorter karst evolution process driven by MR, increased flow fluxes and larger conduit diameters at depth facilitate the formation of extensive vertical permeable tunnels along faults, while simultaneously inhibiting conduit enlargement at the water table.

These findings reveal distinct modes of karstification for MC and MR, underscoring the significant influence of thermal and chemical heterogeneity on karst evolution. This study provides deeper insights into carbonate reservoir dynamics and offers practical implications for enhancing the efficiency of hydrothermal resource exploitation and geological CO_2 storage.

Keywords: Karst evolution, Mixing corrosion, Retrograde solubility, Synergistic effect, Hydro-thermal-chemical coupled model

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv – Machine translation. Verify with original.