

Listvenites and listwaenites – a review of controlling factors and feedback processes allowing complete peridotite carbonation

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Listvenites (or listwaenites) form by metasomatic transformation of serpentinized peridotites into carbonate-quartz rocks due to extensive reaction with CO₂-bearing aqueous fluids, which adds > 30 wt% CO₂ to the rock. Although a rare rock type, they are highly interesting because they are natural analogues for optimal mineral carbonation [1] and potentially form in the cold forearc mantle wedge, modulating deep carbon cycling [2]. A review of listvenite occurrences shows that quartz and magnesite directly replace serpentine in low temperature (*T*) systems (< ~150 °C; e.g. [3]) while at higher temperatures the reaction path involves talc-magnesite (e.g. [4,5]). Using thermodynamic fluid infiltration-fractionation models that simulate flow-through reaction experiments, we quantify expected changes in volume, mass, solute transfer (e.g. Mg, Si mobility), redox conditions and pH with reaction progress in dependence of protolith composition, infiltrated fluid composition, temperature and pressure. The models agree well with experiments [6] and natural observations of high-*T* carbonation but have limitations at low-*T* where kinetic effects limit the approach to equilibrium. Our modelling and assessment of typical CO₂ concentrations in metamorphic/hydrothermal fluids highlight that listvenite formation requires very high time-integrated fluid flux, which in turn requires dynamic renewal of permeability despite reactive volume expansion. As most known listvenites crop out along tectonic contacts between crustal and ultramafic rocks in ophiolites that delineate major orogenic sutures, key factors controlling CO₂ supply are deviatoric stress and related deformation. Listvenite microstructures indicate that important hydro-mechanical-chemical feedback processes allowing continued fluid flux during carbonation are brittle (possibly reaction-induced) fracturing and vein formation [7], reaction-enhanced ductile deformation [8], and local mass redistribution due to solute transfer. These feedback processes critically influence carbon flux pathways and the extent of CO₂ sequestration, but are not yet well understood as they are challenging to reproduce experimentally and by modelling.

[1] Hansen et al. (2005), (<https://doi.org/10.2113/gscanmin.43.1.225>)

[2] Kelemen & Manning (2015), (<https://doi.org/10.1073/pnas.1507889112>)

[3] Kelemen et al. (2022), (<https://doi.org/10.1029/2021JB022352>)

[4] Menzel et al. (2018), (<https://doi.org/10.1016/j.lithos.2018.06.001>)

[5] Cutts et al. (2021), (<https://doi.org/10.1029/2021GC009989>)

[6] Sieber et al. (2022), (<https://doi.org/10.1007/s00410-022-01905-w>)

[7] Menzel et al. (2022a), (<https://doi.org/10.5194/se-13-1191-2022>)

[8] Menzel et al. (2022b), (<https://doi.org/10.1038/s41467-022-31049-1>)

M.D.M acknowledges funding of Junta de Andalucía (Postdoc_21_00791)