Exploring natural analogues for CO_2 storage: listvenites along regional fault zones in the Zermatt-Saas Unit (Western Alps, Italy)

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In the last decades many studies focussed on carbon capture and storage (CCS) to find a possible remedy to reduce the increase of anthropogenic carbon dioxide (CO_2). In geological reservoirs, CO_2 can be trapped by mineral carbonation which plays a crucial role in CCS, being almost irreversible, involving the chemical reaction in aqueous environment between CO_2 and Mg- and/or Ca-rich minerals, where CO_2 is converted into solid carbonates. In nature, listvenite, a rock mainly composed of Mg-Ca-carbonates, quartz and Cr-mica (fuchsite), documents natural CO_2 sequestration. Indeed, listvenites are the result of the extensive alteration of ultramafic rocks by CO_2-bearing fluids, which involved the substitution of olivine, pyroxene and serpentine by Ca- and Mg-carbonates. To date, very little is known about the kinetics and rate of this reaction, spanning from weeks (serpentinites) to thousands of years (peridotites). First listvenitic fault breccias in mantle serpentinites of the Western Alps were reported in the Aosta valley from the Rocca di Verra-Breithorn massif and the abandoned quarry of Sizan, both in the Ayas valley and the Zermatt-Saas Zone (Dal Piaz & Omenetto, 1978). We studied carbonated serpentinites from the Zermatt-Saas Zone (Corno del Camoscio, Western Alps, Italy; Dal Piaz et al., 2010) which underwent fluid-mediated natural carbonation. Hydrothermal carbonation is spatially associated to Oligo-Miocenic brittle faults of the Aosta-Ranzola system (Bistacchi et al., 2001). Field structural study identified two main strike-slip fault sets (N-S and NW-SE striking) controlling fluid flow, with voluminous carbonation observed mainly along the NW-SE-striking set. We collected structurally-controlled samples along a reaction front from serpentinite to listvenite close to a major fault zone, aiming to relate the CO_2-rich fluid/rock interaction with mega and meso-structures. The petrographic study, along with SEM-EDS maps, microprobe chemical analyses and X-ray powder diffraction (XRPD) have allowed us to identify the phase assemblages along the reaction front: from a Mg-silicate rich serpentinite, with minor quartz, magnesite and dolomite to a fully carbonated listvenite composed of quartz, fuchsite and Mg-carbonates, with relict brucite. Interestingly, microstructures in the samples collected close to the serpentinite show carbonates pre- and syn-kinematic to the ductile fabrics. Thus, our study identified a more complex history of fluid-mediated carbonation, defined by a two-phase process: the first carbonation occurring during ductile deformation, and the second one during brittle faulting. Qualitative and quantitative XRPD data enabled us to calculate a mass balance to model the rate of reaction and the composition of the original fluids. Preliminary results indicate a structural control on the fluid drainage and the role of brucite to dominate the carbonation reaction, as reported by experimental results of Campione et al. (2024).

Bistacchi A. et al. (2001) - The Aosta–Ranzola extensional fault system and Oligocene–Present evolution of the Austroalpine–Penninic wedge in the northwestern Alps. Int. J. Earth Sci., 90, 654-667, https://doi.org/10.1007/s005310000178.

Campione M. et al. (2024) - Microwave-driven carbonation of brucite. Journal of CO_2 Utilization, 80, 102700, https://doi.org/10.1016/j.jcou.2024.102700.

Dal Piaz G.V. et al. (2010) - Geologia. In: Leonoris C. (Ed): Percorso Geologico-Pedologico di Cimalegna. Parco Naturale Alta Valsesia, 25 p.

Dal Piaz G.V. & Omenetto P. (1978) - Brevi note su alcune mineralizzazioni della Falda Piemontese in Valle d'Aosta. Ofioliti, 3, 161-176.