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Evidence for crustal-scale fluid infiltration during the Alpine Orogeny

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The main part of the Mont-Blanc massif (External French Alps) is constituted of a Hercynian granite, which mineralogy and chemical composition is rather homogeneous at the massif's scale. A large metasomatic zone has been evidenced in the central part of the Mont-Blanc granite, outcropping only along Glacier de Leschaux, where a digitated metasomatic front is clearly visible. Metasomatized rocks have also been sampled further south in the inner part of the massif, during digging of the Mont-Blanc tunnel.

Metasomatized rocks are characterized by replacement of quartz and alkali minerals by intense precipitation of biotite and chlorite. These secondary phyllosilicates have different compositions than the Alpine biotites and chlorites found in the granitic protolith. Biotite and chlorite related to metasomatism are indeed more silica-rich and present a much higher X_{Mg} number than the granitic minerals. In average, X_{Mg} = 0.65-0.70 in the metasomatic zone whereas X_{Mg-MZ} = 0.30-0.45 in the Alpine biotite and chlorite, which suggest that the metasomatic fluid is Mg-rich.

Mass balance calculation based on comparison of whole rock chemical composition of metasomatized rocks with the granitic protolith evidence large mass transfer. Metasomatized rocks are depleted in SiO_2, Al_2O_3 and alkali elements, and are strongly enriched in MgO and Fe_2O_3 (up to +3932 % and +407 % respectively). In granitic shear zones, most of mass change is usually related to silica gains/loss. However, in the metasomatic zone described here, mass loss due to silica depletion is partially or totally compensated by gains of MgO and Fe_2O_3. Metasomatism thus results from intensive interaction between the Mont-Blanc granite and a fluid extremely rich in MgO and in a lesser extent in Fe_2O_3.

Carbon isotope data from veins associated with the metasomatic zone range within 8.82 ‰ and 10.75 ‰. These values are much lower than those of the Helvetic sediments surrounding the Mont-Blanc massif ($\delta^{13}C$ = -4.10 ‰ to +3.90 ‰) and slightly lower than mantellic values ($\delta^{13}C$ = -5 ‰ to -8 ‰). From carbon isotope data and mass balance calculation, the metasomatic fluid is interpreted as a mantle-derived fluid having interacted with organic matter deep in the thrust pile. This deep-seated fluid percolates up to middle-crust levels probably through vertical crustal-scale shear zones.