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Characterization of mafic rocks at the crust-mantle transition zone: insights from the ICDP-DIVE Project (5071_1_A, Val d'Ossola, Ivrea-Verbano Zone, Italy)

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The composition and origin of the lower continental crust (LCC) is difficult to assess due to the diversity of granulite facies rock types, compositional contrasts between terrains and xenoliths, and the nonunique interpretation of seismic data. Seismic data alone cannot distinguish between different mafic granulites, leading to uncertainties in LCC models. The Ivrea-Verbano Zone (IVZ) in the Alps provides key insights into lithological variability, preserving a Paleozoic felsic lower crust modified by Lower Permian mafic underplating. We present whole-rock data from the 909.5 m borehole 5071_1_A (Megolo) of the ICDP-funded DIVE project. From this borehole granulite facies mafic and metasedimentary rocks were retrieved.

A systematic sampling strategy was applied, with 6–12 cm samples collected at ~10 m intervals. The main mafic lithologies identified on-site, classified by mineral modal proportions, include:

- **Gabbro-norites** (~41.9 vol.%): Opx + Pl ± Gt (<5% Gt)
- **Garnet-bearing gabbros** (~25.5 vol.%): Cpx + Pl + Gt (5–30%) ± Amp ± Opx
- **Garnet-granulites** (~25 vol.%): Mafic granoblastic rocks with 30–75% Gt
- **Intrusive gabbros** (~4.6 vol.%): Cpx + Pl ± Opx
- **Pyroxenites** (~3 vol.%): Opx + Cpx ± Ol

Geochemical data show no clear trends within units or with depth. Mafic rocks are generally depleted in radiogenic elements (K, Th, U) compared to felsic units, correlating with gamma ray logging data. Although slight variations in major oxides, rock density, and gamma logs are observed, they do not effectively differentiate mafic lithologies. Using trace element parameters, we reclassified field-defined samples based on distinct geochemical characteristics. Gabbros and gabbro-norites are now distinguished by Mg# (gabbros <0.55; gabbro-norites >0.55) and Eu anomaly (gabbros <1.6; gabbro-norites >1.6). Both have higher La/Sm ratios (>1) than garnet-granulites and intrusive gabbros (<1). Garnet-granulites exhibit scattered Mg# and lower Ba anomaly (<3), expressed as $Ba^* = [Ba_n/((Rb_n + K_n)/2]\text{-}1$, compared to gabbros and gabbro-norites. Intrusive gabbros generally have high Mg# (>0.6) and high Gd/Yb ratios (>1.7). This geochemical reclassification highlights overlaps between field-defined units, particularly among gabbro-norites, garnet-bearing gabbros, and garnet-granulites. Weighted bulk composition aligns with the lower range of LCC reported in the literature.