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# Multi-stage subduction metasomatism of the sub-arc mantle revealed by peridotite xenoliths from Lanyu, Taiwan, the northern Luzon arc

**DR. KUO-LUNG WANG, PHD**[1,2], DUYEN THI TRAN[1], FATMA KOURIM[1], YOSHIYUKI IIZUKA[1] AND HAO-YANG LEE[1]

[1]Institute of Earth Sciences, Academia Sinica
[2]Department of Geosciences, National Taiwan University

Peridotite xenoliths from Lanyu (LY) island, hosted in basalt and basaltic andesite of the northern Luzon volcanic arc (Philippine Sea Plate), provide direct constraints on the composition and multistage evolution of the sub-arc mantle. The xenolith suite is dominated by refractory harzburgites and lherzolites characterized by low whole-rock $Al_2O_3$ (~1.04–2.37 wt.%), high Mg# (0.88–0.91), high olivine forsterite (Fo 90.5–91.7), and estimated melting degrees of ~20–25%. Two-pyroxene thermometry yields equilibrium temperatures of 935–1079 °C, in agreement with mantle-wedge geotherms beneath the arc. Together, these features indicate highly depleted mantle residues produced by high-degree mantle wedge melting. Chondrite-normalized PGE patterns show relative depletion of PPGE compared to IPGE, further supporting a residual character. Re–Os isotope systematics yield sub-chondritic $^{187}Os/^{188}Os$ ratios (0.1211–0.1268), low $^{187}Re/^{188}Os$ (~0.02–0.13), and γOs values of −5.5 to −0.95, with Re-depletion model ages ($T_{RD}$) of 182–1177 Ma, indicating the presence of inherited Proterozoic to early Phanerozoic depleted mantle domains beneath the arc. Superimposed on this refractory framework, trace-element systematics record subduction-related metasomatism, characterized negative Nb–Ta–Ti anomalies and enrichment in fluid-mobile elements (Ba, Cs, Pb). Sr–Nd isotopes define coherent mixing arrays requiring three components: (i) a depleted mantle wedge source, (ii) an altered oceanic crust–derived fluid component, and (iii) a sediment-derived component. During metasomatism, $^{87}Sr/^{86}Sr$ ratios are variable and locally radiogenic (0.7035–0.7077), whereas εNd(t) remains moderately depleted (+0.5 to +2.4), indicating decoupled Sr–Nd behaviour and efficient transfer of radiogenic Sr by slab fluids. Mineral-scale disequilibrium features provide evidence for later-stage melt–rock interaction. Chromian spinels show strong core–rim zoning, with Cr# increasing from ~0.27–0.62 in cores to ~0.42–0.71 at rims and higher $TiO_2$ toward rims. Clinopyroxenes exhibit $Na_2O$-enriched rims (up to ~0.29 wt.%). These features indicate reactive percolation of melts through previously depleted peridotite, resulting in refertilization and redistribution of incompatible elements. Overall, the LY xenoliths document a multistage history involving (1) formation and preservation of ancient depleted mantle residues, (2) subsequent fluid-dominated slab metasomatism, and (3) late melt–rock interaction, highlightingpronounced mantle wedge heterogeneity beneath the western Pacific subduction system.