An overview of the volatile systematics of the Lau Basin – resolving the effects of source variation, magmatic degassing and crustal contamination

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The Lau Basin erupts lavas with a range of geochemical features reflecting a complex history of interaction involving different mantle sources. The Valu Fa Ridge (VFR) and Mangatolu Triple Junction (MTJ) region has lavas with arc-like characteristics, Niuafo'ou Island (NV), Peggy Ridge and Central and Eastern Lau Spreading Centers (PR, CLSC and ELSC) erupt mid-ocean ridge basalt (MORB)-like volcanics, whereas the Rochambeau Bank (RB) has features akin to ocean island basalt (OIB). To characterize the volatile systematics of these various regions, we report a comprehensive study of 39 submarine lavas from these various eruptive centers encompassing analyses of the noble gases (He, Ne, and Ar) and carbon (CO_2) – both isotopes and abundances - together with other major volatile phases (H_2O, S, Cl, and F).

Helium isotope ratios of the NV, MTJ, CLSC, and ELSC are MORB-like for the most part except for differentiated lavas that tend to have lower, more radiogenic $^3He/^4He$ values. The RB has considerably higher $^3He/^4He$ ratios (up to 23 R_A in this work) which extend as far south as the PR. The influence of 'plume-like' sources in the RB is also apparent in Ne isotopes: RB samples follow a trend similar to Hawaiian basalts in 3-isotope neon space. However, RB lavas have lower $^{40}Ar/^{36}Ar$ (300-730) and higher [^{36}Ar] than CLSC and ELSC, suggesting greater air contamination. Elemental He/Ne ratios ($^3He/^{22}Ne_S$ and $^4He/^{21}Ne^*$ where S = solar and * = nucleogenic) are high throughout the Lau Basin and identify the Lau mantle as one of only two high $^3He/^4He$ provinces worldwide with such an enrichment of He relative to Ne.

Magmatic CO_2 and $\delta^{13}C$ fall in the range 7 to 350 ppm and -28 to -6‰, respectively. RB lavas have less [CO_2] and slightly lower $\delta^{13}C$ than CLSC and ELSC. The lowest values are found among MTJ lavas. These lavas also have the highest [H_2O], [F], [Cl], and [S] whereas the PR, ELSC and CLSC have the lowest. RB has intermediate [H_2O]. We estimate primary [CO_2] in primary melts using [CO_2]-$d^{13}C$ relationships, and find that RB lavas have higher [CO_2] (935 ± 168 ppm) than ELSC/CLSC (638 ± 115 ppm). They also possess higher initial $d^{13}C$ values, consistent with observations at other hotspot-related localities. However, there are no discernible differences in primary CO_2/Nb ratios between mantle sources characterized by high $^3He/^4He$ and MORB-like ratios. On the other hand, reconstructed values are considerably higher than that envisaged for depleted MORB mantle based on olivine-hosted melt inclusions.