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Geochemical Signatures of Felsic Rocks in Modern Intraoceanic Settings and Implications for Archean Greenstone Belts

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Felsic volcanic rocks are abundant in ancient greenstone belts and important host rocks for volcanogenic massive sulfide (VMS) deposits. Dacites and rhyolites are the immediate hosts for about half of all VMS deposits, related to anomalous heat flow during rifting, fractional crystallization, and partial melting of basaltic crust. For over 30 years, geochemical signatures of these rocks (e.g., F-classification of Archean rhyolites) have been widely used to identify possible hosts for VMS deposits in greenstone belts, based on processes of melt generation and fractionation and inferred geodynamic setting. Until recently, it has not been possible to rigorously compare these findings to modern oceanic settings owing to the limited sampling of felsic volcanic rocks from the oceans. In particular, it remains unclear to what extent the differences between modern and ancient oceanic crust may be related to the lower mantle temperatures, thinner crust, and subduction-related processes in present-day settings. In this study, we have compiled high-quality analyses of more than 2,200 unique samples of modern submarine felsic volcanic rocks (>60 wt % SiO_2) from mid-ocean ridges, ridge-hotspot intersections, intraoceanic back-arc basins, island arcs, and ocean islands. This new compilation shows significant geochemical diversity, spanning the full range of compositions of silicic lavas in VMS-forming environments. In the F-classification, FI-like felsic volcanic rocks are mostly related to calc-alkaline magmatism in arc-related assemblages, and FII signatures are interpreted to be from intracontinental arc-backarc environments. FIIIa signatures are mainly found in tholeiitic rocks from rift-related intraoceanic island arc and back-arc assemblages, and FIIIb-like dacites and rhyolites are from mid-ocean ridges and back-arc spreading centers. LREE-depleted FIV signatures are interpreted to be mainly from forearc and intra-arc rift settings and are largely absent in Archean greenstone belts. However, in modern oceanic settings, we show that felsic volcanic rocks ranging from FII to FIV dacites and rhyolites can occur within a single arc-backarc system. We interpret the diversity of modern arc-backarc assemblages to reflect highly variable i) stress regimes, ii) crustal thicknesses, iii) presence or absence of slab-derived fluids (dry melting versus wet melting), and iv) mantle anomalies. These differences are revealed by a combination of principal components analysis, unsupervised hierarchical clustering, and supervised random forest classification of the compiled data. We suggest that the melting conditions recorded by the felsic volcanic rocks are related to short-lived microplate domains, specifically where multiple overlapping spreading centers have contributed to basin opening, as in the northern Lau Basin. The felsic volcanic rocks in modern arc-backarc systems share strongly depleted mantle signatures and well-known subduction-related chemistry (strong LILE enrichment in combination with strong negative Nb-Ta anomalies and HREE depletion). This contrasts with felsic volcanic suites in Archean greenstone belts, a high proportion of which show HFSE and HREE enrichment due to a less depleted mantle, a lack of wet melting, and highly variable crustal contamination. We suggest that thickened oceanic crust in the Archean may have resulted in widespread buoyant microplate domains that were obducted during amalgamation, preserving the felsic volcanic rocks with HFSE and HREE enrichment.