Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36688

Structure–Reactivity Screening Framework for Volcanic Silicates in Enhanced Rock Weathering

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Enhanced Rock Weathering (ERW) effectiveness depends on how crystal chemistry and microtexture govern the liberation of Ca and Mg from silicate frameworks, rather than on bulk composition [2]. We present a structure–reactivity screening framework that quantifies the ability of crystal structures to release alkaline cations and integrates microstructural exposure metrics to identify volcanic silicate feedstocks with high early reactivity. Candidate materials are grouped as massive mafic lava, vesicular scoria, and mafic sand to highlight mechanistic controls rather than provenance.

Our workflow combines quantitative phase analysis using QXRD with internal standards to estimate crystalline and amorphous fractions with microtexture imaging using SEM, BSE-EDS, and EPMA to resolve phase distributions, Fe-oxide armoring, and grain-scale occlusion. We calculate reactive specific surface area (RSSA), quantified using phase-resolved perimeter and area exposure on BSE images following our image analysis approach for surface exposure [3]. We then construct a Structure–Reactivity Index (SRI) from four terms: framework connectivity, expressed as a Q^n proxy from phase assemblage and Raman or ^{29}Si NMR where available, RSSA of Ca and Mg carrier phases, extent of Fe-oxide or low reactivity co-phases that reduce exposure, and amorphous content. Reactivity benchmarks use weak acid neutralization and soil simulant leaching to estimate early alkalinity flux under ERW relevant pH.

New screening results show that feedstocks with higher amorphous fractions and vesicular or fine particulate microtextures yield greater initial alkalinity fluxes, which aligns with dissolution trends for less polymerized or disordered silicates [1]. Al rich, plagioclase dominated assemblages respond more slowly unless milling increases RSSA, consistent with slower aluminosilicate dissolution under near-neutral soil conditions [1,2]. Fe-oxide coatings reduce effective exposure of Ca and Mg silicates, lowering SRI and initial flux. These relationships explain why materials with similar bulk chemistry diverge in ERW performance and support structure aware parameterization of reactivity models [3,4].

[1] Heřmanská, Voigt & Oelkers (2022), Chemical Geology 597, 120807.

[2] Haque, Khalidy & Chiang (2023), ACS Earth and Space Chemistry 7, 1294–1305.

[3] Santos, Araujo, Amidi, Khalidy & Chiang (2024), Goldschmidt 2025, DOI: 10.13140/RG.2.2.32670.40004.

[4] Santos, Khalidy, Basimalla, Roobroeck, Collinson, Manga & Marangu (2024), European Mineralogical Conference 2024, DOI: 10.13140/RG.2.2.18832.83201.