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Four decades of using (and misusing) the chemical index of alteration as a monitor of paleoweathering and paleoclimate reconstructions: what does the future hold?

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More than 40 years and 8000 citations since its inception, the chemical index of alteration (CIA) remains as the hallmark for quantifying in a single number the effects of chemical weathering to interpret paleoweathering and paleoclimate using major-element geochemistry. By focusing on aluminum (A), calcium (C), sodium (N), and potassium (K), the CIA tracks the alteration of feldspars, the major weatherable minerals dominant in the upper continental crust. Since its initial application, the CIA has been used to interpret the effects of climate on the compositions of modern sediments, weathering profiles, paleosols, and sedimentary rocks on Earth and Mars. A popular but misguided modification of the CIA equation led to the generation of the chemical index of weathering (CIW) that failed to accurately account for K-bearing minerals. Other key misunderstandings about using the CIA stem from its inability to: (1) track mafic-phase alteration due to the absence of iron (F) or magnesium (M), and (2) separate compositional inputs inherited from the source, sediment transport, diagenesis, and later hydrothermal overprinting. Consequently, a tandem of 2D ternary-diagram projections (A-CN-K, A-CNK-FM) were created to better isolate the roles of multiple processes. However, limitations remain from using only three apex variables, which results in differing combinations of elements at the apices and makes the diagrams difficult to compare. Future use of the CIA now focuses on the simultaneous assessment of A, CN, K with F and M (accommodating the expanded mafic index of alteration [MIA]) in 3D tetrahedral projections. By example, the A-CN-K-FM tetrahedron incorporates most major elements important to sedimentary petrogenesis and (in many cases) logical grouping of element pairs (C+N, F+M), which produces distinct pathways that enhance interpretive power. While the most common use of the CIA and derivative products lies in assessing surficial rocks, ample opportunity remains to apply the approach to hydrothermally altered rocks. Expanding tetrahedron apices beyond A-CN-K-FM to include silicon or rearrangements of elements based on conditions or behavior offers more interpretive potential. Even with exciting new directions, the fundamental root of the CIA still shows why it has become the benchmark for evaluating alteration using major-element geochemistry.