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Tracking the loss of rock organic carbon during oxidative weathering

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The oxidative weathering of rock organic carbon (ROC) is an important atmospheric CO_2 source in the long-term carbon cycle. Fine-grained sedimentary rocks, or shales, are the primary ROC reservoir on Earth's surface. However, stratigraphic heterogeneity in shale successions generates spatial variability in ROC distribution, complicating efforts to quantify oxidative loss through comparisons of weathered profiles and unweathered bedrock. Moreover, other reduced phases in the weathering zone, including sulfide minerals and fresh labile organic carbon, can obscure signals directly attributable to ROC oxidation.

We present a new framework to quantify ROC oxidative loss by integrating (1) micro-scale molybdenum (Mo) phase distribution and (2) organic geochemical characterization across shale weathering profiles. During deposition, Mo is predominantly associated with organic matter, sulfides, and clay minerals. Upon oxidative weathering, Mo released from ROC and sulfides is preferentially scavenged by secondary Fe oxides. We quantify Mo re-adsorption efficiency using controlled batch experiments to reconstruct primary Mo inventories. By coupling reconstructed Mo abundances with Mo partitioning among host phases in both bedrock and weathered samples, we estimate the magnitude of ROC oxidative depletion. Independent constraints from organic composition and thermal maturity profiles provide complementary indicators of ROC loss and help disentangle contributions from modern carbon inputs.

We apply these approaches to two shale systems with different weathering contexts. The Middle Eocene Cozy Dell Formation (Santa Ynez Mountains, California) preserves intact weathering profiles with minimal modern organic carbon addition (<5% by radiocarbon data), providing an ideal natural laboratory for isolating ROC oxidation. This is complemented by paired core and outcrop samples from the Late Cretaceous Eagle Ford Group (South Texas), which enable direct stratigraphic comparison between parent rock and weathered equivalents. Together, these sites help quantify ROC oxidative loss across different climatic and tectonic settings, refining estimates of this long-term CO_2 source.