

Mass extinctions, climate change, and enhanced terrestrial weathering?: The end-Permian and end-Guadalupian events compared

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The Middle and Late Permian are characterized by two mass extinction events that significantly impacted life in both the marine and non-marine realms. A number of causal mechanisms have been proposed including a bolide impact, flood volcanism, coalbed methane combustion, and seafloor methane clathrate release. These mechanisms have in common that they predict significantly elevated atmospheric CO₂ levels and rapid global warming [1], and it has been suggested that both extinction events share a common cause [2]. Both events are recognized in the non-marine realm by a shift in fluvial style [3], a negative δ¹³C anomaly [1], and significant extinctions of vertebrates and plants [1, 4]. During the Middle and Late Permian, Antarctica and Australia represented the southernmost extent of Gondwana. Previous study of the end-Permian event using paleosols preserved at Graphite Peak, Antarctica [5], indicated significantly enhanced chemical weathering in the earliest Triassic relative to the latest Permian on the basis of enhanced leaching (Ba/Sr ratio), and a doubling in REE accumulation in earliest Triassic paleosols formed in ~1/20th of the time of their latest Permian counterparts, immediately following the shift in fluvial style, and coincident with the negative δ¹³C excursion. There is also a significant redox shift in the earliest Triassic toward extremely reducing conditions recorded at Graphite Peak and elsewhere in Gondwana [5]. In contrast, new results for the end-Guadalupian event from Portal Mountain, Antarctica, show no change in leaching, decreased accumulation of REE, decreased Al/Si ratios, steady CIA values, and increasing salinization ratios. Together, these results imply steady or even decreasing chemical weathering, which suggests either a very different cause for the end-Guadalupian event or that it was not as significant a CO₂ increase as the end-Permian event.

[1] Retallack (2009) *GSA Bull.* **121**, 1441–1445. [2] Retallack *et al.* (2006) *GSA Bull.* **118**, 1441–1445. [3] Ward *et al.* (2000) *Science* **289**, 740–743. [4] Ward *et al.* (2005) *Science* **307**, 709–714. [5] Sheldon (2006) *Palaeogeog. Palaeoclim. Palaeoeco* **231**, 315–321.

Microbial oxidation and mineralogical alteration of biotite

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The lithotrophic Fe (II)-oxidizing, nitrate-reducing enrichment culture reported by Straub *et al.* (1996) was shown to grow via oxidation of structural Fe (II) in biotite as well as chemically reduced smectite. The ability of this culture to oxidize Fe (II) in insoluble Fe (II)-bearing phyllosilicates is consistent with its previously demonstrated capacity for oxidation of solid-phase Fe (II)-bearing minerals (siderite and magnetite) and Fe (II) sorbed to mineral surfaces (Weber *et al.* 2001). Oxidation of fine silt/clay sized biotite particles was detected by a decrease in 0.5M HCl-extractable Fe (II) content and simultaneous nitrate reduction. No nitrate loss or Fe (II) decrease was observed in suspensions without microorganisms. Approximately 10⁷ cells were produced per μmol Fe (II) oxidized, in agreement with previous estimates of the growth yield of lithoautotrophic circumneutral-pH Fe (II)-oxidizing bacteria. Growth ceased after ca 5% of the total Fe (II) content of the biotite was oxidized. Mössbauer spectroscopy confirmed structural Fe (II) oxidation. Microbial oxidation of structural Fe (II) in biotite resulted in release of K and some Si into solution. No release of Fe or Al was observed. High-resolution TEM revealed amorphous Fe (III) oxide nanoprecipitates on the biotite surface, as well as stacking disorder structures. The observed polytype change resulted from conversion of trioctahedral layers into dioctahedral layers due to migration of Fe out of the octahedral sheet. XRD results show a lower d₀₆₀ value for oxidized biotite compared to the native material. Our results suggest that in addition to the well-known ability of microorganisms to accelerate weathering of primary minerals through production of carbon dioxide and organic ligands, microorganisms can be directly responsible for the initial oxidation step of biotite weathering.

[1] Straub K. L., Benz M., Schink B. & Widdel F. (1996) *Appl. Environ. Microbiol.* **62**, 1458–1460. [2] Weber K. A., Picardal F. W. & Roden E. E. (2001) *Environ. Sci. Technol.* **35**, 1644–1650.