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Paleosols as Archives of Environmental Change in Deep Time

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Paleosols develop at the geosphere-atmosphere interface and potentially provide an archive of environmental conditions at the time of their formation. Although paleosols from deep time can be difficult to recognize due to the masking of pedogenic features by metamorphism and deformation, they may record transient (i.e. time-dependent) events which are often difficult to recognize in other geological proxies. Paleosols from the Archean and Paleoproterozoic are rare and complex to study, but offer an opportunity to gain insight into what may be relatively short-scale temporal variations in the Earth's atmospheric composition. For instance, it is widely believed that atmospheric oxygen saturation rose from <10E-05 present atmospheric level (PAL) in the Archean to >10E-02 PAL at the Great Oxidation Event (GOE) at ca. 2.4 Ga. Until recently however, chemical or physical evidence from paleosols for earlier oxygenation events were generally thought to be lacking. Recent studies of paleosols from eastern India (Keonjhar Paleosol, Singhbhum Craton) and South Africa (Nsuze Paleosol, Kaapvaal Craton) have provided chemical evidence for transient Mesoarchean atmospheric oxygenation at ca. 3.0 Ga. These paleosols are considered to preserve the earliest known vestiges of terrestrial oxidative weathering, signifying a transient, early oxygen accumulation in the Earth's atmosphere. This has far-reaching implications from both atmospheric and biological evolutionary perspectives in that chemical signatures preserved in these Mesoarchean paleosols are thought to signify the presence of molecular oxygen at levels higher than those attributable to photo-dissociation of atmospheric water alone. Such elevated levels of atmospheric oxygen could only be due to the presence of a sufficiently large biomass of micro-organisms capable of oxidative photosynthesis. Although the Archean-Paleoproterozoic paleosol geological record is fragmentary and geochemical signatures are not necessarily straightforward to interpret, these paleosols provide an opportunity to study the nature and timing of atmospheric compositional changes at a crucial time in the Earth's evolutionary history.