Chlorite and biotite weathering, Fe\textsuperscript{2+}-rich corrensite formation, and Fe behavior under low $P_{O_2}$ conditions and their implication for Precambrian weathering

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ABSTRACT

Fresh and weathered granite from drill cores in Tono, Gifu, Japan, was examined to understand weathering products and the mechanisms of chlorite and biotite weathering under low $P_{O_2}$ conditions. A fresh sample from 365 m depth, a slightly weathered light-green sample from 367 m depth, and a nearly fresh sample from 369 m depth (but with brown stains on fractures), were investigated. The XRD, SEM, EMPA, and TEM analysis of green grains present within chlorite, biotite, and plagioclase grains and in veins was found to be Fe\textsuperscript{2+}-rich corrensite [about 40 wt\% FeO with Fe/(Fe + Mg) = 0.94]. The corrensite is interpreted to have formed from chlorite and biotite via a dissolution-precipitation mechanism. The $<$2 \textmu m fraction of the weathered sample had an Fe\textsuperscript{2+}/\Sigma Fe value of 0.69, which, when combined with the presence of amorphous Fe\textsuperscript{3+} (hydr)oxides confirmed by TEM, indicates that the Fe\textsuperscript{2+}/\Sigma Fe value of corrensite is $>0.69$. These results indicate that on dissolution of chlorite and biotite, Fe\textsuperscript{2+} was transported as Fe\textsuperscript{2+} and precipitated as Fe\textsuperscript{2+}-rich corrensite and a part of the dissolved Fe\textsuperscript{2+} was oxidized to amorphous Fe\textsuperscript{3+} (hydr)oxides under low $P_{O_2}$ conditions. The formation of Fe\textsuperscript{2+}-rich corrensite and that of Fe\textsuperscript{2+}-rich smectite or vermiculite in the laboratory at 1 atm of $P_{CO_2}$, and $\leq3 \times 10^{-5}$ atm of $P_{O_2}$ (Murakami et al. 2004) suggest that a possible Fe\textsuperscript{3+}-bearing product during Precambrian weathering is Fe\textsuperscript{2+}-rich sheet silicates but not siderite.

Keywords: Weathering, corrensite, Fe behavior, low $O_2$, atmospheric evolution, granite, TEM

INTRODUCTION

Biotite and chlorite are major Fe-bearing minerals at the surface of the continental crust, and their weathering processes under oxic conditions have been intensively studied (Barnhisel and Bertsch 1989; Fanning et al. 1989; Righi and Mennier 1995). Biotite and chlorite are converted to kaolinite through vermiculite (or smectite) with the formation of Fe\textsuperscript{3+} (hydr)oxides. The formation of mixed-layer minerals of vermiculite with biotite and chlorite often occurs during oxic weathering (e.g., Kogure and Murakami 1996; Banfield and Murakami 1998). Similarly, various geological and geochemical records have shown that atmospheric oxygen increased during the Precambrian (Holland 2006). The chemical compositions of Precambrian paleosols, fossil weathering profiles, are one of the important parameters used to estimate the quantitative pattern of changes in $P_{O_2}$, suggesting that the first irreversible oxygen rise in the Earth’s history took place between about 2.5 and 2.0 Ga (Rye and Holland 1998). Oxidation of Fe\textsuperscript{2+} especially under low $P_{O_2}$ conditions is central to such an estimation because the rate of Fe\textsuperscript{2+} oxidation is directly related to $P_{O_2}$ levels (Stumm and Lee 1961). Almost all Fe\textsuperscript{2+} dissolved from primary Fe\textsuperscript{3+}-bearing minerals such as biotite and chlorite is oxidized to form Fe\textsuperscript{3+} (hydr)oxides under modern, oxic conditions. In contrast, under low $P_{O_2}$ conditions, it is likely that part of the dissolved Fe\textsuperscript{2+} released from the dissolution of primary minerals flows out of the weathering profile and some precipitates as secondary Fe\textsuperscript{3+}-rich minerals as well as Fe\textsuperscript{3+} (hydr)oxides. Therefore, quantitative estimation of oxygenation of a paleosol requires a deeper understanding of the weathering processes of biotite and chlorite under low $P_{O_2}$ conditions.

The samples used for the present study were collected from...