

Biotite-controlled weathering characteristics of residual regolith derived from Cretaceous tonalite - quartz diorite, western Peninsular Ranges, southern California, USA: A case study

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Abstract

In California, tonalite and quartz diorite are common intrusive rocks underlying the western parts of the Cretaceous Sierra Nevada and Peninsular Ranges batholiths. Because they underlie such an extensive area, how they weather to form residual regolith is deserving of study. I therefore undertook a detailed petrological and chemical investigation aimed at understanding how such regolith developed in a well exposed ~6 m section derived from K-feldspar free tonalite to quartz diorite located in Santa Margarita Ecological Reserve (SMER) within the western part of the Peninsular Ranges batholith. Ten corestone, 10 saprock, and 3 soil samples were analyzed for 11 major elements, 19 trace elements, and 14 rare earth elements (REE).

Throughout the section of saprock and soil, biotite is significantly more weathered than are hornblende, plagioclase, and quartz. XRD work shows that the product of the alteration of biotite is predominantly vermiculite. This transformation involves an expansion perpendicular to (001) that is estimated to be as large as 40%. Over time such expansions apparently stressed the host rock beyond the brittle limit, and as a result, an intricate and complex fracture system formed in the saprock. In centered molar p(A)-p(CN)-p(K) ternary space, the alteration of biotite to vermiculite also produced a well-defined whole rock compositional linear trend that is directed away from the p(K) apex. This trend is consistent with the removal of K mass from biotite during the development of the saprock system, an interpretation that is supported by mass balance calculations using Ti as a reference frame. Most trace elements that commonly substitute in the crystal lattice of biotite also are affected by weathering, and in the case of Cu and Ni may have accumulated in the interlayer position vacated by K. In contrast to K, with the exception of sample HW1 (277 cm depth), and samples HW4 (237 cm depth) through HW6

(177 cm depth), the REE within the section of saprock are little affected by weathering. Given that the REE are only mobilized by acidic solutions, the above characterizations imply that solutions responsible for the alteration of biotite within the saprock section above and below HW1, and HW4 through HW6 were near neutral to weakly alkaline in character, an interpretation that is supported by pH measurements (7-7.5).

Unlike the above generalizations, significant mass loss of Si, Al, Ca, and Na occur in sample HW5 at 208 cm depth. Such losses likely reflect the alteration of plagioclase under acidic conditions. In addition, the same alteration process is responsible for the loss of Pb, Sr, and Ga mass within the same sample, and imply that within the intricate complex network of saprock fractures, isolated fluid pathways allowed acidic solutions to reach deep within the saprock profile. In contrast, REE data show that a significant addition of HREE mass occurred within not only HW5, but also in HW4 and HW6. Such results imply that near neutral to alkaline solutions saturated with the HREE moved through HW4-HW6 after the episode(s) of acidity responsible for the plagioclase alteration in HW5.

Significant loss of REE mass in HW1, which lies adjacent to and below the above zone of HREE accumulation, is evident. However, losses of Ca, Na, Pb, Sr, and Ga mass did not occur. It is therefore likely that at some time in the past fluids entering HW1 were slightly acidic, but not acidic enough to leach the above major and trace elements from plagioclase.

The physical and geochemical properties of the overlying soil are unlike that characteristic of the saprock. For example, acidic solutions attacked plagioclase, biotite, and apatite leaching and removing Ca, Na, Mg, K, and P mass. In addition, the dissolution of apatite indicated by the loss of P mass, resulted in depletions in HREE mass. None of the above elemental mass accumulated in the directly underlying saprock, and must have been removed downslope and out of the plane of the studied section.