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Biotite controlled chemical alteration of granodioritic–tonalitic saprock: Exploring the use of sieving to enhance compositional linear trends

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ABSTRACT

The Peninsular Ranges, southern California, USA, commonly contains eroded sections of regolith composed of (1) saprock enclosing corestone or (2) alluvial deposits overlying plutonic/metamorphic basement. In this paper, we present a study focused on evaluating the chemical weathering patterns exemplified by type 1 regolith. In an attempt to enhance the coverage of altered samples about calculated compositional linear trends, the <45 μm fractions were separated from saprock samples and were chemically analyzed.

Though Alfisol is common within the study area, due to erosional exhumation, such soil is absent at the specific site sampled during this investigation, and colluvium directly overlies saprock and corestones. Mean annual precipitation ranges from 25 cm–51 cm with a mean annual air temperature of 13 °C–18 °C.

In centered p(A), p(CN), and p(K) ternary space, A, CN, and K are compositions representing molar percentages of Al_2O_3, $CaO^* + Na_2O$, and K_2O, respectively, in the sum of A, CN, and K. CaO^* is the molar percent of CaO following correction for CaO in apatite. Centering preserves the geometrical relationships between plotted samples, but moves them to the center of the ternary diagram.

Saprock samples plot about a linear compositional trend directed away from the p(K) apex. Using orthogonal projection, the average weathering intensity value, *t*, of the bulk saprock samples is 0.09 (±0.04). When the sieved <45 μm fractions are considered along with the bulk saprock samples, a similar linear compositional trend is calculated, but sieved fractions plot closer to the A–CN join, and have an average *t*-value of 0.89 (±0.04). Hence, inclusion of the sieved fraction extended the coverage of altered samples about the weathering trend.

Using Na as a reference frame, a statistically significant loss of 10% (+9/−8%) and 14% (+6/−5%) K and P mass, respectively, occurred during the development of saprock. The loss of K mass is attributed to the alteration of biotite to hydroxy-interlayered vermiculite and mixed-layer biotite/vermiculite, while the loss of P mass is due to the dissolution of apatite. In addition, statistically significant increases in Si (6% ± 4%) and LOI (56% (+37/−30%)) mass occurred. The increase in Si mass reflects either, or both, illuviation of small amounts of kaolinite into the prominent crack system observed at the study site, or the addition of pedogenic silica. Such increases are apparently the result of processes that were operative in the now erosionally removed section of Alfisol. The results of the above elemental mass changes produced a statistically significant increase in bulk mass of 5% ± 3%.

The results of our work suggests that the inclusion of <45 μm fraction chemical data can significantly enhance the coverage of calculated linear compositional trends, and could be a useful investigative tool for future studies.

1. Introduction

Regolith developed on plutonic rocks commonly consists of saprock and/or saprolite. In the lower parts of such sections, corestones, representing spheroidal enclaves of unweathered bedrock, are embedded in saprock. Saprock represents in situ weathered material in which less than 20% of the weatherable minerals are altered. In contrast, in saprolite more than 20% are affected by in situ chemical alteration (Graham et al., 2010).

The highly eroded and dissected Peninsular Ranges of southern California, USA, commonly contain eroded and partially exhumed sections of regolith composed of either (1) saprock enclosing corestone or (2) variably thick alluvial deposits overlying plutonic/metamorphic basement. Alfisols, Inceptisols, and Entisols in various degrees of preservation commonly cap both of the above types of regolith (Web Soil Survey, 2014). In this paper, we present a study that focuses on evaluating the chemical weathering pattern and statistical properties of a compositional linear trend at a sample site composed of type (1) regolith.

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As described later in this paper, to avoid the statistical and mathematical problems associated with closure, we utilized the techniques advocated by Aitchison (1986) and von Eynatten et al. (2003) to calculate compositional linear trends. In addition, in an attempt to gain better coverage of resulting trends, we used sieving to split from our collection of saprock a <45 μm fraction. Our focus on the <45 μm fraction stems from the fact that compositional linear trends as defined by von Eynatten et al. (2003) are anchored by the geometric mean of the parental material (i.e., corestone), while the other end member composition is controlled by mixtures of clay derived from the weathering of the parental silicate mineral fraction. Hence, the composition of the latter material should be magnified in finer grained fractions. The U.S. Standard Sieve Mesh #325, the smallest sieve commonly available for dry sieving (Folk, 1974), allows separation of the <45 μm fraction.

In the following pages, we first discuss the study area and our sampling and geochemical analytical methods. Petrologic and clay mineralogy data are then provided to frame the geologic context of this study. The mathematical and statistical methods used and the results of our calculations of compositional linear trends, weather intensity factors, and changes in bulk and elemental mass that accommodated the conversion of corestone to saprock at the sample site are then provided. We then close with a discussion of the potential significance of our work.

1.1. Site characteristics and climate

The study site occurs at 33° 33.9030′ N, and 116° 30.3391′ W, east of the San Jacinto fault zone, southern California (Fig. 1). Within this region, medium-grained, Cretaceous granodioritic to tonalitic rocks of the Peninsular Ranges batholith, along with selvages and screens of older metamorphic rocks are nonconformably overlain by sandy and gravelly alluvial deposits of the Pleistocene Bautista Formation (Sharp, 1967). Locally, younger Quaternary alluvial deposits are abundant.

The study site chosen for detailed investigation consists of ellipsoidal to sub-spherical granodioritic–tonalitic corestones embedded in saprock (Fig. 2). Though Alfisol is a common soil within the general study area, due to erosional exhumation, soil is absent at the specific site sampled during this investigation, and colluvium directly overlies saprock and corestones.

For the general area containing the study site, the mean annual precipitation ranges from 25 cm–51 cm with a mean annual air temperature of 13 °C–18 °C (Web Soil Survey, 2014).

2. Methods

2.1. Sample extraction

At the study site, a large ~50 kg sample of corestone was extracted and subsequently broken into five parts (Fig. 2). From an ~20 cm deep and ~30 cm wide trench, saprock samples were collected adjacent to the corestone. Three blocks of saprock were removed from the trench and were labeled 1, 2, and 3. The latter two blocks were split into two parts, and were labeled 2A, 2B, 3A, and 3B (Fig. 2).

2.2. General laboratory procedures

2.2.1. Thin sections and point counting

Approximately 100 cm^3 fragments of saprock were vacuum impregnated with epoxy before being cut into thin sections. In addition, thin sections were cut from each of the five parts of the large ~50 kg corestone sample. In order to distinguish K-feldspar from plagioclase, all thin sections were chemically stained with sodium cobaltinitrite ($Na_3Co(NO_2)_6$). Using a grid spacing of ~2.0 mm, between 133 and

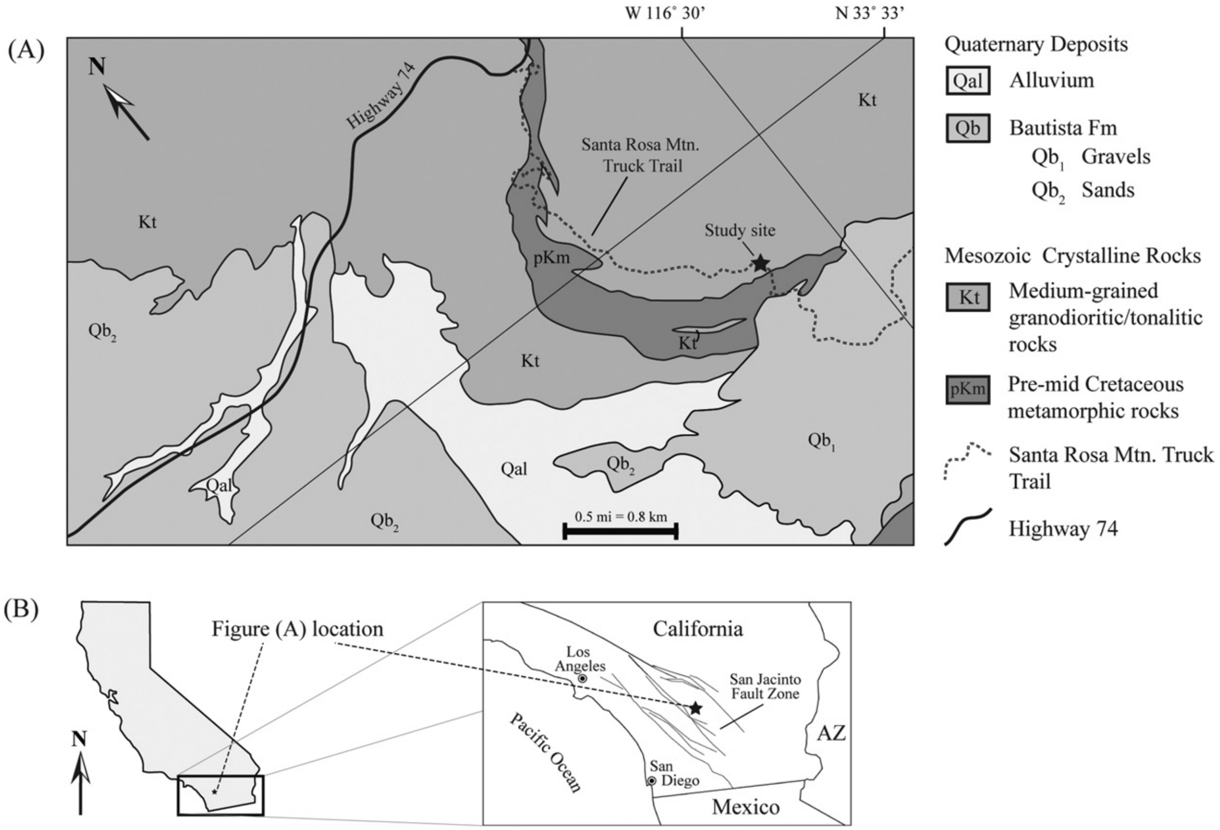

Fig. 1. (A) Location of study site within the Peninsular Ranges, California. Map modified from Sharp (1967). (B) Map showing study area lying within SW California, east of San Jacinto fault zone. Study site located at 33° 33.9030′ N, 116° 30.3391′ W.