Assessing the statistical significance of mass and volume changes in the development of saprock from corestone near the Elsinore fault zone, San Diego County, California: potential implications for ground shaking events

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Abstract

Estimations of bulk mass, elemental mass, and volume changes that accompany the development of saprock and saprolite from corestone provide insight into the physical and chemical processes that result in the weathering of bedrock. The transformation of bedrock and corestone to saprock and saprolite is commonly viewed as an isovolumetric process. In contrast, our work conducted at two sites near the Elsinore fault zone, southern California shows that the development of saprock from corestone was accompanied by a positive volumetric (dilational) strain. Thin section observations reveal that at site 1 (gabbro), ~4.0 km from the Elsinore fault zone, pyroxene and biotite have been preferentially altered to clay minerals during the formation of saprock from corestone, while amphibole and biotite are only weakly weathered. In contrast, at site 2 (granite), ~3 km from the Elsinore fault zone, plagioclase and biotite are more strongly weathered. CIA values confirm that site 2 has undergone more extensive weathering than site 1. Probabilistic approaches were used to evaluate the statistical significance of the physical and chemical changes that accompanied the development of saprock from corestone. During this phase of our work 95% confidence intervals, were estimated using parametric small sample statistics. Results indicate that the change in bulk mass (T) was -0.2% ± 0.9 at site 1 and -6% ± 3 at site 2. At site 1 changes in elemental mass (τ) were as follows: -5% ± 1 Ca, -2 % ± 1 Na, -3% ± 1 Mg, +11% ± 3 Mn, -5% ± 2 Zn, -5% ± 3 V, -28% +24/-18 Ni, +35% +36/-28 Cu, -27% +5/-4 K, and -40% +25/-18 Ba. In contrast, at site 2 changes in elemental mass (τ) were as follows: -7% ± 4 Si, -45% +5/-4 Ca, -43% +5/-4 Na, -18% ± 7 K, -29% +8/-7 Mn, -15% ± 8 Mg, +16% +8/-7 Ti, +70% +29/-25 Sc, +27% +28/-23 Cr, -35% ± 4 Sr, -39% +13/-11 Y, -8% ± 5 Zr, and +84% +60/-45 Hf. The above losses in elemental mass are attributed to leaching of cations from plagioclase (Si, Ca, Na, Sr, Ba, Y), biotite (K, Ba, Mn, Mg), pyroxene (Mg, Ni, Ca), and amphibole (Mg, Zn, K, Ca, Ni, Na, V) by fluids migrating through the corestone-saprock layer. In contrast, gains in elemental mass are probably the result of the leaching of cations from minerals in overlying soils and/or saprock areas elevated with respect to each study site. Leached cations carried by such fluids were then absorbed onto clay minerals. Though only small to no changes in bulk mass occurred at sites 1 and 2 the development of saprock from corestone was accompanied by a positive volumetric strain (ε) of 13% ± 3% at site 1, and 28% ± 8% at site 2. The nonparametric bootstrap technique was also used to assess the reliability of the parametric results. It generated nearly identical results. These observations and data are inconsistent with the commonly observed isovolumetric development of saprock from corestone in non-seismogenic areas. The proximity of the two sites studied during this investigation to the Elsinore fault zone, and the many ground shaking events from earthquakes generated along this fault have likely contributed to the observed positive volumetric strains. Such an interpretation is consistent with recent numerical modeling which suggests that kilometer

wide areas adjacent to large-slip faults like the Elsinore will be damaged during rupture events. Therefore, at the two sites sampled here, saprock development from corestone is interpreted to be the result of the dynamic interplay between iron oxidation of biotite as it is altered to expandable clays, partial dissolution of various mineral species, gravity-driven fluid flow, and ground shaking during earthquakes.