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Deep weathering in the semi-arid Coastal Cordillera, Chile

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The weathering front, the boundary beneath Earth's surface where unweathered bedrock is converted into weathered rock, is the base of the critical zone. Typically, this front is located no more than 20 m deep in granitoid rock in humid climate zones and its depth is commonly linked to oxygen transport and fluid flow. To disclose the depth of the weathering front in dry climate, we conducted a drilling campaign in the semi-arid climate zone of the Chilean Coastal Cordillera to investigate a complete weathering profile by mineralogical and geochemical methods as well as geophysical borehole measurements.

We found multiple weathering fronts of which the deepest is located at 76 m beneath the surface. Dioritic rock is weathered to varying degrees, contains core stones, and strongly altered zones featuring intensive iron (Fe) oxidation and high porosity. We found more intense weathering where fracturing is extensive, and in these zones porosity is higher than in bedrock. Only the uppermost 10 m feature a continuous weathering gradient towards the surface. Porosity was preserved throughout the weathering process, as secondary aluminium-silicon minerals were barely formed due to the low fluid flow.

We suggest that tectonic fractures act as major pathways for oxygen to greater depth, generating porosity by oxidation of Fe-bearing minerals. The depletion of soluble elements is also concomitant with high fracture density and highest elemental loss is detected in the proximity of planar fractures or fractures zones. The orientation and dip angle of the fractures are consistent with the arrangement of tectonic faults in the area and the general strike and kinematics of the Atacama fault system. We interpret that most of these fractures have formed during the Late

Mesozoic activity of the fault system. Further fractures in the study area may be related to the cooling of the diorite or may be modern and have formed either by stress relief during denudation or through Fe oxidation. We hypothesise that advection of fluids and gases through tectonic fractures sets deep weathering at multiple weathering fronts, since we found elevated degrees of chemical depletion close to larger fractures and no continuous weathering gradient exists. Although the fluid flow is minor, the slow turnover of the weathering zone provides sufficient time to form and preserve these deep weathering features. For the drill sites' denudation rate of 29.6 t km^{-2} $year^{-1}$ from cosmogenic nuclides, corresponding to about 11 m Myr^{-1}, the entire weathering may get turned over about every 7 Myr, if steady state denudation is assumed.

This study is prerequisite to detailed investigation of the microbial processes involved at weathering at great depth.

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