Overview of weathering in a small monolitholigic drainage basin: “La Trucha”, Sierra de Comechingones, Córdoba, Argentina

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The term *weathering* is used in the Earth Sciences to denote the *in situ* breakdown and alteration of rocks and minerals. In the near surface environment, pressure, temperature and water availability differ significantly from those prevailing at the crust’s interior. Because of this disequilibrium, exposed rocks are easily attacked, decomposed and eroded by various chemical and physical surface processes. The term weathering conveys, as well, a close linkage with atmospheric conditions (i.e., weather). At any rate, weathering involves a set of processes that prepare rock material for transport, and such movable debris or *regolith* is defined as “the mantle of *in situ* and transported material that covers the landscapes across the world” (Scott and Pain, 2009).
Carson and Kirkby (1972) identified two distinctive erosional regimes: *transport-limited*, and *weathering-limited*. Stallard and Edmond (1983) recognized that weathering-limited environments are characterized by little or no soil development, and as a result sediment derived from such source areas is relatively unaltered.
The assessment of weathering intensity and rate in a transport-limited regime is a relatively straightforward process because the existence of thick, well-developed weathering profiles allow the use of varied methodologies, such as the so-called “absolute” approach, through the “benchmark mineral” method or a myriad of relative indices, like the chemical index of alteration (CIA), the chemical index of weathering (CIW), and other similar ratios (e.g., Depetris *et al*., 2014 and references therein). The evaluation of weathering is more difficult in a weathering-limited scenario because a significant part -if not all- of the regolith has been removed and the landscape is composed of bare exposed rocks and patches of relatively thin regolith layers and accumulated sediment and/or incipient soil development. For these reasons, there are relatively few studies which have probed into the nature of weathering in semi-arid, mostly weathering-limited environments, such as those prevailing in Argentina’s Sierras Pampeanas.
The small studied drainage basin (~2 km^2), herein known as “La Trucha”, is located in the southern portion of the Achala Batholith, within the Sierra de Comechingones. It is one of the southernmost ranges of the Sierras Pampeanas in central Argentina, which consist of Paleozoic basement blocks bounded by faults. In this contribution we compare the original country rock with the overlying regolith, seeking to establish relative gains and losses of major and trace elements, and REE that granite (Devonian) undergoes in a small and typical weathering-limited drainage basin. In so doing we seek to determine a stepping stone that will allow us to probe further into the nature of weathering in this region.
Weathering indices are useful to understand and evaluate element mobility during the chemical alteration of rocks. Several indices are defined in the literature (e.g., Depetris *at al.*, 2014 and references therein); most of them compare the concentration of an immobile element with several mobile components. The Chemical Index of Weathering (CIW) was calculated here to characterize the chemical alteration processes in the study area. The CIW considers the Al_2O_3 as the immobile component, while CaO and Na_2O are the mobile components because they are readily leached during weathering:

$$CIW = 100\ [Al_2O_3/(Al_2O_3 + CaO + Na_2O)]$$

This index does not take into account the potassium because it may be adsorbed onto clays through ion exchange during chemical alteration. In the studied area, CIW delivered more meaningful results because coarse-grained regolith samples appeared relatively enriched in K-feldspar. Therefore, the difference of CIW between source rock and sediment reflects more precisely than other indices the extent of chemical weathering experienced by loose material.
La Trucha drainage basin is representative of hundreds of first and second order streams that constitute the upper catchments of the fluvial system that dissects the Achala Batholith. The landscape is typical of a denuded scenario and our current investigation shows that it is an example of a classical weathering-limited regime with a moderate to low rate of chemical denudation. The landscape is a relict of conditions prevailing during Carboniferous Gondwana times. In as much as weathering occurs at a slower rate than erosion, there are no soil profiles that would assist in the assessment of weathering intensity.
Mechanical weathering appears to play a significant role in rock breakdown. The result is a regolith distributed all over the drainage basin, which is significantly affected by water-transported sorting. Therefore, there is a coarse-grained regolith that is characterized by a slightly larger relative abundance of detrital feldspar than the

original country rock, and exhibits little alteration. Plagioclase shows the same alteration in both, granite and regolith samples, which occurs primarily at the cores of zoned plagioclase crystals, and some Fe-oxide segregations that develop on the crystal edges of biotites. The geochemical signature of this regolith material is a CIW that is slightly different from the granite (i.e., a CIW which is only 1% higher than the country rock), depleted mainly in Ca, Fe and Mg. Likewise, a set of trace elements and REE which are proxies of heavy accessory minerals, are depleted with respect to granite (Fig. 1).

Fine-grained regolith accumulated in topographic lows (i.e., in floodplain settings) is significantly finer than the coarse-grained regolith. Plagioclase, which is in a lesser proportion than in the country rock, exhibits a higher degree of alteration, as plagioclase crystals are almost completely replaced by clay minerals and sericite. Biotite displays a more intense segregation of Fe-oxides, and K-feldspar shows a slight alteration that affects the plagioclase-rich domains of perthite. In terms of its chemistry, though slightly more depleted in soluble elements, it is very similar to the coarse-grained regolith, thus implying that the main process is physical breakdown (Fig. 1). In connection with trace elements and REE, the country rock-extended normalized diagrams show a very similar pattern, which reflects the effect of sorting, associated with the larger abundance of accessory minerals resistant to weathering (Fig. 1). CIW is barely higher than in the coarse fraction counterpart (i.e., 1.6% change with respect to granite).

The A-CN-K and A-CNK-FM ternary diagrams reveal the effects of erosion and sorting, as the coarse-grained regolith and fine-grained regolith samples correspond to a coarse residue comparatively enriched in feldspars (and quartz), thus implying that the mud-fraction with high concentrations of clay minerals has been removed from the high-energy drainage basin. The positive Eu/Eu* - CIW correlation for the regolith samples also reveals the geochemical effect of high-energy sorting on the residual material.

This study performed in a pilot area of the highest ranges of the Sierra de Comechingones allowed the assessment of the effects of a dominant weathering-limited erosional setting, which is not coherent with the current landscape, but it projects an image of a prevailing mechanical weathering which operates in synergy with moderate chemical attack that mainly affects plagioclase and biotite.

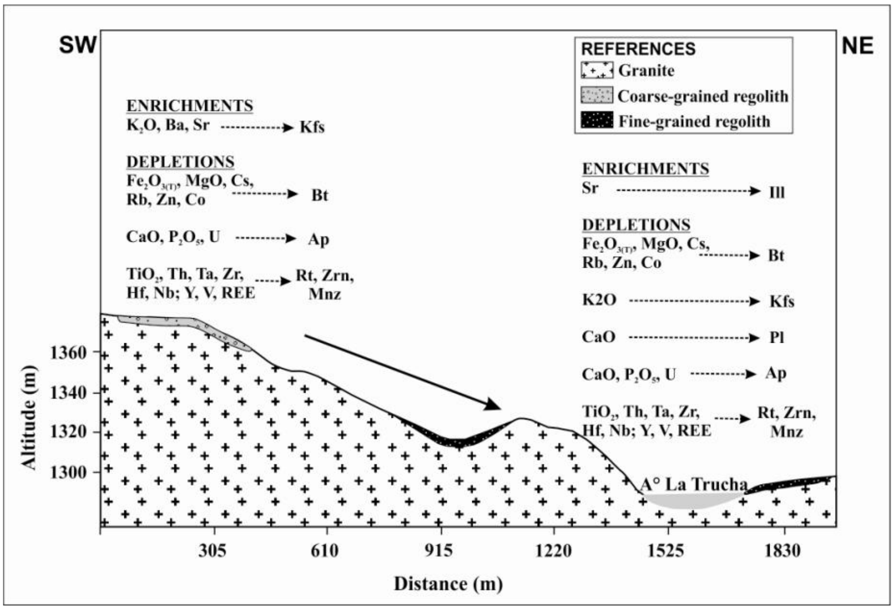

Fig. 1: Schematic section of the studied drainage basin, showing the geochemical and mineralogical changes that occur in the coarse- and fine-grained regolith samples, as compared with the granite country rock. Mineral abbreviations are after Kretz (1983).

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