Mineral and Compositional Changes During Weathering of Continental Rocks

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Background

Weathering affects slope stability of geologic formations, formation of agricultural soils, longevity of engineered building materials, as well as recording a record of paleoclimate. Goldich (1938) noted that mafic rocks are more susceptible to weathering than felsic rocks. The igneous bedrock exposed in the St. Francois Mountains (1.48 Ga) in Missouri have undergone periodic weathering from the Cambrian to modern day, and showcase the history of weathering and its products in this region. These rocks thus offer an opportunity to evaluate the Goldich thesis.

Objectives

- Observe differences in mineral and chemical compositions during weathering by collecting and analyzing rock samples from the St. Francois Mountains.
- Reveal how weathering processes alter over time and reflect climate change.
- Observe weathering differences between mafic (Mg and Fe rich) vs. felsic (feldspar and silica rich) rocks.
- Relate the composition and mineralogy of the weathered mafic and felsic rocks to evaluate their potential as a source for Cambrian-aged Davis Formation shale.
- Evaluate weathering patterns during the Cambrian.

Methods

- Collected relatively unweathered samples of the Butler Hill Granite (~1480 my), Grassy Mountain Ignimbrite (rhyolite; ~1480 my), Davis Fm. shale (Cambrian aged), and diabase-basalt dikes. We also collected weathered paleosol horizons forming on each of the previous. Discolored fracture surfaces from the unweathered samples were trimmed and discarded using a rock hammer.
- Examined samples in the lab for mineral content using microscopy techniques.
- Pulverized a portion of each sample using a tungsten steel shatter box.
- One split of each sample was mixed with SpectroBlend 44 µm powder and pressed for X-ray fluorescence (XRF) chemical analysis. The percent error for granite was less than 3% for Si, Na, and Al; and between 15-20% for K, Mg, and Fe. The diabase percent error for the same elements were all greater than 15%.
- A second split of pulverized sample was gravity separated in a water column and the clay-size fraction (after being put on a glass slide and dried) was used for X-ray diffraction (XRD) analysis. XRD analyses were conducted for the granite, diabase, and Davis shale samples using CuKα radiation source.

Results and Discussion

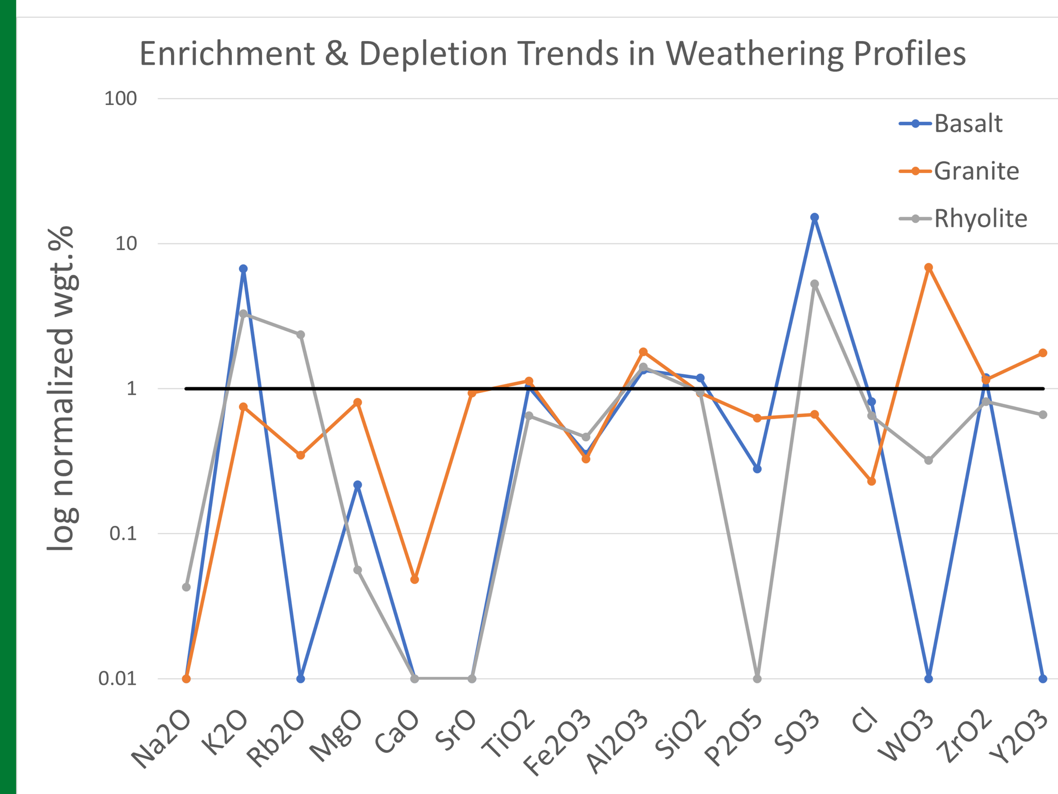

Fig. 1: XRF Enrichment-depletion trends of weathered rock samples normalized to respective unweathered parent source rock.
- Enriched Elements: K, Al, Si
- Depleted Elements: Na, Mg, Fe, Mn, P

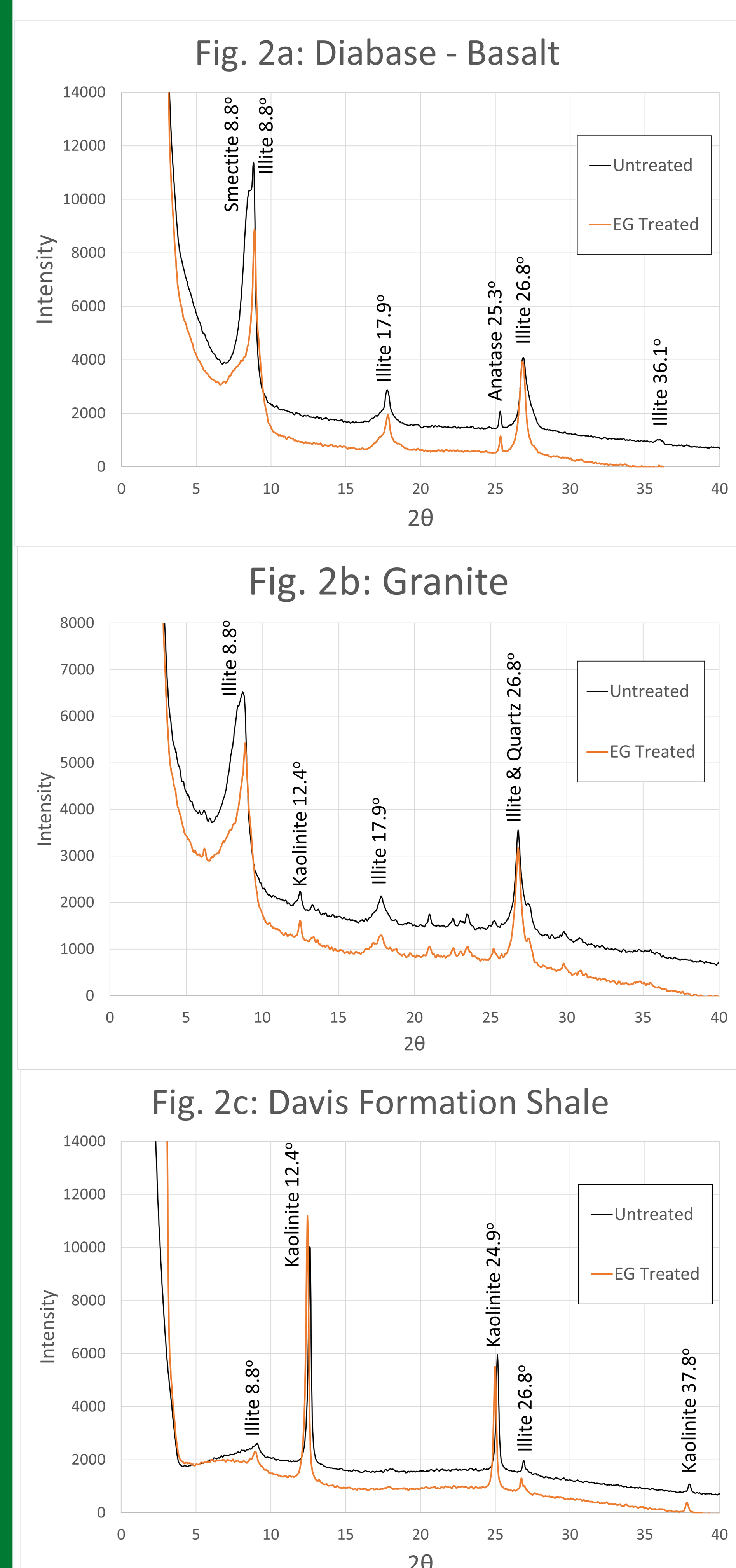

Fig. 2 XRD Data From Clay Sized Fraction:
a is the weathered diabase which was dominated by illite with subordinate smectite and anatase: b is the weathered granite which was dominated by illite and kaolinite: c is the Davis Formation shale, which was dominated by kaolinite with lesser illite. The shale data does not match the diabase or granite source rocks, therefore the provenance study is inconclusive.

XRF Discussion:

- There was an unexpected enrichment of K in both the unweathered and weathered diabase. This enrichment may have occurred due to crustal contamination as the magmas for the diabase ascended through the continental crust. The K enrichment trend was retained in the weathering profile.
- Fe oxides are normally insoluble during weathering however, Fe was depleted in the weathered basalt. We believe this is due to the samples being weathered in a reducing environment.

XRD Discussion

- Clays are the primary weathering product of the rock samples we collected. This was not a surprise considering the mineral makeup of the granite is approximately 65% K-feldspar. Clays form as a weathering product of the alumina and silica released from the feldspar as it weathers.
- Anatase (TiO_2) showed enrichment in the weathered diabase sample. While it is common to find TiO_2 products in mafic rocks, we were surprised to see a prominent peak of it on XRD. The high concentration of Ti was likely due to the diabase dike forming from an ultramafic mantle.

Outcrop Photos

Fig. 3 Collection Sites: The Lamotte Sandstone prevented the weathered rhyolite and basalt from being physically eroded away.
a Butler Hill Granite.
Both b and c show the Grassy Mountain Ignimbrite (rhyolite) and the diabase dike. C also shows the highly weathered diabase dike and a pyrite impregnated rhyolite boulder field (gypsum was found here).
d shows the collection point for the Davis Fm. shale sample.

Conclusions

- The weathered diabase was depleted in iron; therefore, it may have weathered in a reducing environment. We hypothesize that sulfate in water was reduced in reactions with the bedrock, forming sulfide that reacted with the Fe-II to precipitate pyrite. Modern weathering of this outcrop has produced hematite and gypsum.
- Regarding climate change, illite produced during Cambrian weathering (?) suggests Missouri's climate was more temperate when compared to tropical climates in other regions at this time.
- The presence of the K bearing illite clays as a weathering product of diabase may influence soil nutrients. This suggests that K deficiency is not the reason for poor agricultural productivity in the Ozarkian soils.

Future Experiments

- Have the XRD instrument run with standard quantification to detect trace elements.

- Create a more comprehensive geological profile of the region, which would require the retrieval of samples using drilling and further analysis.

Acknowledgements

Goldich, S. S. (1938). A Study in Rock-Weathering. The Journal of Geology, 46(1), 17–58. http://www.jstor.org/stable/30079586

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