PRF #: 56958-DNI2
Title: Origin of Altered Horizons beneath Nonconformities: Implications for Induced Seismicity and Basin-Scale Fluid Flow
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Activities

PI Bonamici and M.S. student Ke Li have acquired whole-rock geochemical data, performed petrographic analysis of rock thin sections, obtained XRD analysis for mineralogy, and performed SEM-based mapping for mineral chemistry and mineral distribution. M.S. student Ke Li presented her preliminary findings at the Goldschmidt Geochemical Conference in Boston in August of this year. Undergraduate student Mercedes Salazar prepared samples of secondary alteration calcite for oxygen isotope analysis (awaiting final data collection) and assisted with refining the carbonate analytical method in the New Mexico Tech isotope lab. We submitted our proposal to collect samples along the Great Unconformity in Grand Canyon National Park and were granted a research permit for October 2018.

Scientific Findings

Lithology is the single strongest control on alteration degree and the depth of alteration along the nonconformity horizon, as evidenced by the different types and degrees of alteration observed in different crystalline lithologies, including granitic orthogneiss, granitic pegmatite, amphibolite, and biotite schist (Fig. 1).

A combination of textural and mineralogical data allow us to distinguish an order of alteration events at the Gallinas Canyon outcrops: 1) Low-temperature surface weathering destroyed crystalline rock fabrics and rock cohesion and increased rock porosity by breaking down plagioclase, biotite, amphiboles and metamorphic chlorite to clays; 2) burial and compaction of the weathered surface below basin sediments produced a new fabric parallel to the nonconformity by orienting clays; 3) a high-temperature, K-rich fluid moved along the nonconformity, crystallizing metasomatic biotite and locally precipitating K-feldspar in amphibolite and schist lithologies; 4) a high temperature, high-pH (alkaline) fluid moved subparallel to the nonconformity, dissolving silica from felsic granitoid protolith rocks and creating subhorizontal, channel-like, dissolution structures, while precipitating calcite-rich veins and pervasively replacing plagioclase in amphibolite-protolith rocks; and 5) an oxidizing fluid circulated through the altered zone precipitating Fe-oxide and Fe-hydroxide minerals in fractures and, locally, sulfate minerals, like barite and jarosite.

The K-metasomatism in Gallinas Canyon is similar to K-metasomatic events recognized in exposures of the Great Unconformity in Wisconsin and Minnesota in association with 1.4 Ga alkaline magmatism (Medaris et al., 2003; Medaris et al., 2017). By analogy, K-metasomatic and alkaline fluids documented in Gallinas Canyon may record long-distance fluid transmission driven by 1.4 Ga alkaline magmatism in central and southern New Mexico.

Quantitative indices of alteration calculated from whole-rock chemical data vary with alteration degree as expected for granitic orthogneiss but fail to accurately capture degree of alteration in non-granitic rock compositions. Our microscale investigation shows that the bulk chemistry of the altered horizon reflects a mixture of low-temperature weathering and higher-temperature fluid events rather than a single alteration process. We conclude that, whereas weathering had the most profound effect on alteration of the bulk rock chemistry of granitic orthogneiss, the hydrothermal fluid events dominated the alteration chemistry of the schist and amphibolite rocks.

Impacts

This year PRF funding has enabled graduate student Ke Li to attend and present at her first international scientific conference. She presented her work in a session focusing on unconventional reservoirs and had the opportunity to talk to several people about the potential importance of altered horizons for fluid flow. The PI was able to recruit undergraduate Earth Science major Mercedes Salazar to participate in geochemistry research through work on oxygen isotope analysis in the New Mexico Tech Stable Isotope Lab. Mercedes also assisted with thin section analysis and imaging in preparation for other analytical techniques. PRF funding has allowed the PI to continue training her first graduate student as an early career professional. It has also allowed the PI to interact with a new group of professionals in the realms of low-temperature geochemistry and resource-focused geochemistry, areas outside of her previous experience. The PI has been using her PRF-funded research results to plan for a future DOE Basic Energy Sciences research proposal focusing on mineral alteration and fluid-rock interactions.

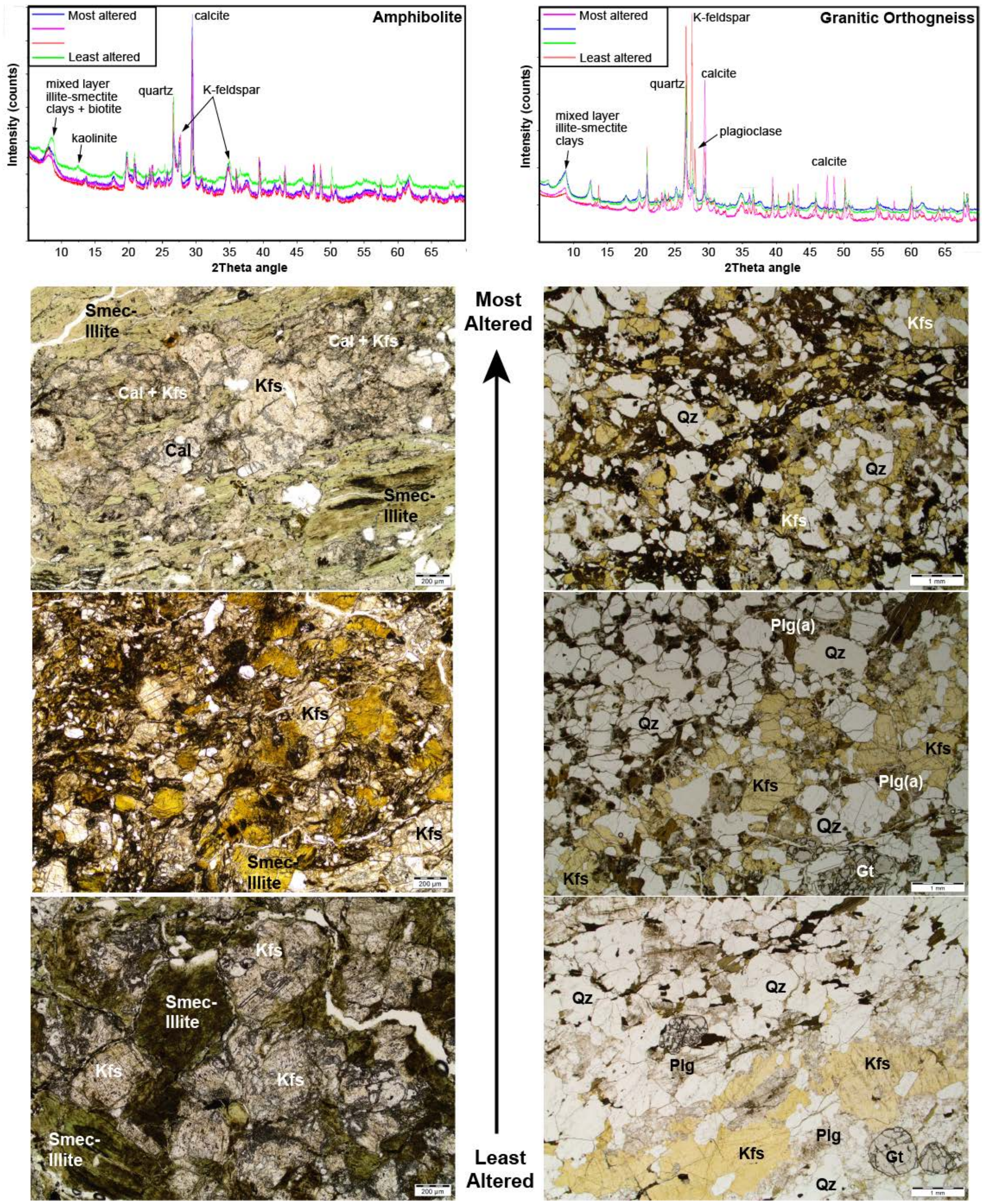

Figure 1. XRD spectra and thin section images showing characteristic alteration at the Great Unconformity in Gallinas Canyon, New Mexico. Right hand column shows alteration of amphibolite. Even in deepest amphibolite samples where the primary amphibolite texture is preserved, plagioclase has been entirely replaced by K-feldspar (Kfs) and hornblende by a mixture of illite-smectite (Smec-illite) group minerals. The left hand column shows alteration of granitic orthogneiss. The primary gneissic texture is lost as all primary plagioclase (Plg) and biotite are replaced by illite group minerals (Plg(a)). The most altered samples also show grain-sized reduced, angular quartz (Qz) and K-feldspar, as well as development of vein-like structures filled with white micas and Fe-oxides, indicating extensive silica dissolution.