Overview/Abstract

Title: Understanding the relationship between the variability of the radiofluorescence signal and the variability in the geochemistry of individual feldspar grains.
PI: Marine Frouin

Geochronologic data provide essential information critical for understanding the rates of Earth's surface processes, environmental changes, and the evolution of life. Advances in dating techniques have fundamentally changed our capacity to piece together our evolutionary past over millions of years. Optically Stimulated Luminescence (OSL) dating is widely used in Geology, Archaeology, and Environmental Sciences, as it is applicable to many types of sediments and contexts. The technique enables us to determine an age corresponding to the most recent exposure of mineral grains to daylight. Generally, the preferred choice of mineral is quartz because of its common occurrence. However, the early saturation of the luminescence signal within quartz at ~200 Gy generally limits its application to the last 200,000 years (considering a dose rate of 1 $Gy.ka^{-1}$). By contrast, potassium (K)-rich feldspar minerals typically display significantly higher dose saturation levels at ~500 Gy, allowing the dating of older deposits up to 500,000 years (considering a dose rate of 1 $Gy.ka^{-1}$).

Over the last eight years, the PI's group has developed a revolutionary new luminescence-based method known as Infrared-Radiofluorescence (IR-RF, Frouin et al., 2015, 2017). The method can be used on K-rich feldspar minerals to determine the age of sediments with a potential upper age limit of around 4 million years (Ma) (Frouin et al., 2017). This method is based on the effects of low-level radioactivity in sediments and its measurable effects on K-feldspar mineral grains deposited with them. However, uncertainty surrounding its upper age limit remains, and further studies on known-age natural samples are required to assess whether the variability of the IR-RF signal is related to variability in the geochemistry of individual feldspar grains. In particular, it is fundamental to identify which element is responsible for producing the IR-RF signal with the highest dynamic range (i.e., saturation at high dose) because the saturation level constrains the age range of time over which IR-RF dating is applicable. The three main objectives and outcomes of this seed grant proposal are summarized as follows:

Task 2: Explore the effect of β-irradiation on the shape of the IR-RF dose-response curve (DRC) of individual feldspar grains. Based on our preliminary observations, we anticipate that some grains will exhibit an increasing IR-RF signal with dose exposure while others will show a decreasing IR-RF signal with dose exposure. Within both categories, the saturation level of the IR-RF signal is expected to vary.

Task 1: Explore the mineralogy variability in feldspar grains from known-age samples. The feldspar minerals can be grouped, according to bulk composition, into K-feldspar and Na-/Ca-rich feldspar (plagioclase). Here, we will analyze the geochemical composition of mineral grains from both groups. While K-feldspar is expected to exhibit a similar geochemical composition, plagioclase feldspar might contain more iron (Fe) and various elements.

Task 3: Evaluate the upper dating limit, accuracy, and precision achievable using IR-RF depending on the mineral geochemistry. We anticipate an upper age limit of IR-RF to be dependent on the geochemical composition of the grains, with variation within samples, across localities, and environments. We hypothesize an age limit of up to ~4 Ma for K-rich feldspars.

Extending the dating limit of luminescence to ~4 Ma will span the temporal gap left by other dating techniques currently on offer and provide a revolutionary tool to allow the dating of the origin of our species and environmental changes during the Pleistocene. The results of this proposed research are critical to pursue external funding from the National Science Foundation (NSF) CAREER grant and the NSF Sedimentary Geology and Paleobiology Program. The present OVPR Seed Grant is the first step of a larger project that seeks to improve the chronology of human evolution by applying this novel IR-RF dating technique to key archeological sites in East Africa.