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ABSTRACT

Constraining the Western Greenland Ice Margin Retreat History and Geometry Using Cosmo Genic Isotope Be-10 Dating. Katy Djambazian (Lehman College, CUNY, Bronx, NY 10468) Dr. Yuri Gorokhovich (Lehman College, CUNY, Bronx, NY 10468) Dr. Vincent Rinterknecht (University of St Andrews, College Gate, St Andrews, Fife KY16 9AJ, Scotland, United Kingdom).

During August of 2014 I conducted field work in Poland and participated in lab work in Scotland. In the field the objective was to map the locations of glacial deposits and find the history of deglaciation in the Tatras Mountains, in both the Polish and the Slovakian side. Deglaciation is important because it helps to establish how climate change affected ice, and how fast the process of melting continued. By knowing rates of historical deglaciations we can better understand current climatic fluctuations. A team composed of professors and students looked for moraines, (evidence of glacial deposits), and mapped the location (at different hiking sites) of where moraines and boulders, that were adequate for testing, were found. I acquired training on glacial geomorphology field techniques and sampling; collected samples will be tested at a later date with surface exposure dating procedures using cosmogenic Beryllium 10 (^{10}Be) isotopes. At the University of St Andrews, Scotland I continued with the lab work processingcosmogenic (rock) samples previously collected in Greenland. Upon geochemical processing these samples will be further prepared in laboratories in France to complete the isotope dating analyses. The data acquired from these analysis's will help to improve estimations of ice thinning rates during the Late Glacial Maximum (10,000 to 13,000 years ago) on the western de-glaciated coastal margin of Greenland and the Western Carpathian Mountains. My field study during the summer of 2014 was conducted as a continuation of work that has beengoing in both in Greenland and the mountains in Europe since the year 2005. The purpose of the study it to reconstruct both the climate of the Tatras Mountains and the dynamic of the glacier retreat during the Late Pleistocene period using glacial deposits to better understand what is happening in the context of global warming today and also to be better prepared for what may take place in the future.

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INTRODUCTION

Surface Exposure Dating (SED) "…utilizes primarily the build-up of Beryllium 10 (^{10}Be) in rock materials over time…" [1], which is produced in-situ within a rock matrix due to exposure of the rock to cosmic rays, and is used to determine the length of time a rock or boulder has been exposed to the sun's rays. This type of examination, at the geochemistry level, is used to determine the geological timeline of events, dating back to thousands of years ago. When examining a rock sample at the geochemistry level and to determine its geological age, the fact must be stated that when rocks are exposed to cosmic (sun) rays, the high energy from the sun is absorbed by the rocks creating Beryllium 10 (^{10}Be) isotopes within the crystals of the rocks, usually in the form of the mineral Quartz. However, for rocks that were once covered by ice from a glacier, the production of ^{10}Be begins once the glacier recedes and the rock is exposed to the radiation from the sun. This is a time when the geologic clock based on ^{10}Be starts working.

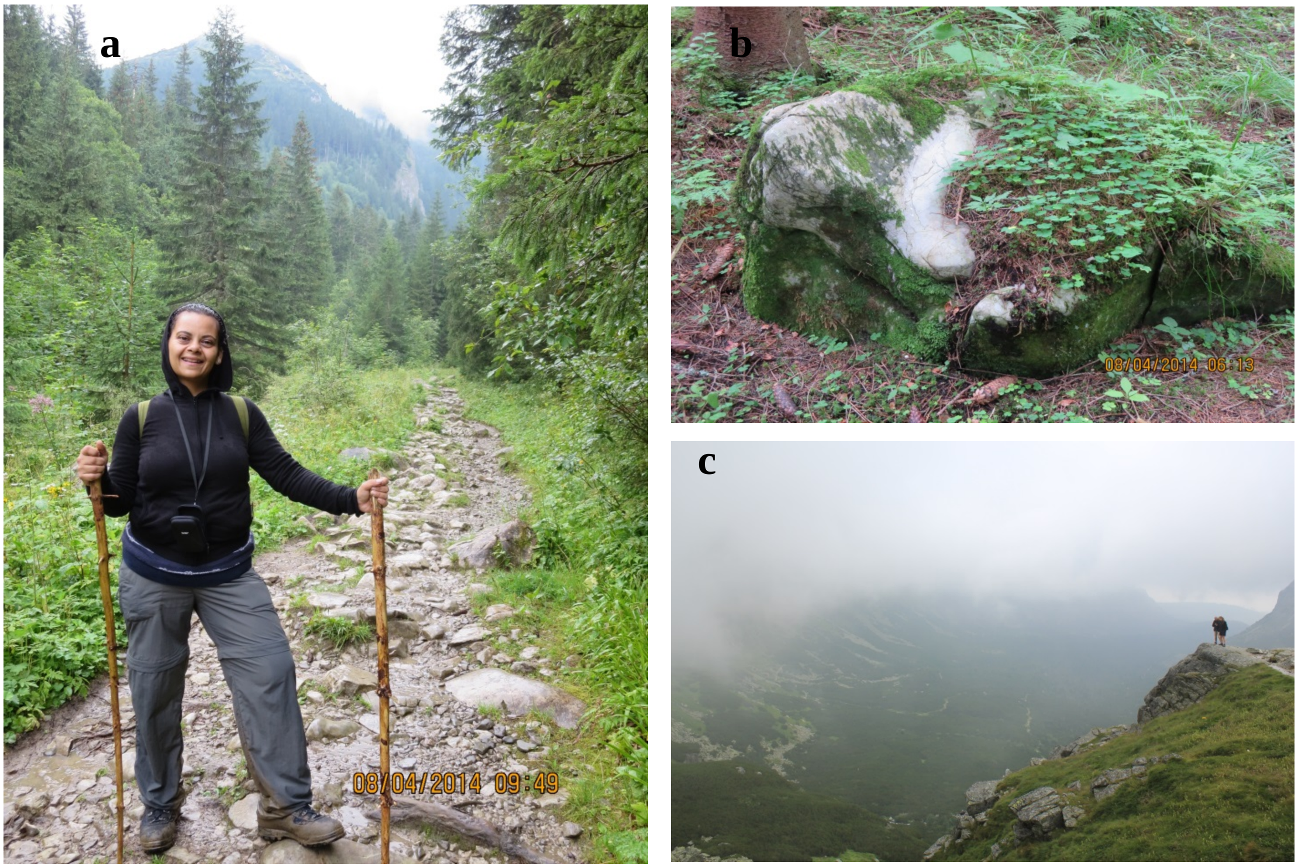
During the Last Glacial Maximum, which is the latest time interval in the history of the Earth when glaciers reached their maximum volume (about 100,000 to 10,000 years ago) (Lambeck *et al.*, 2002), there were more ice sheets or glaciers covering the earth than there are today. When ice sheets or glaciers form, the sea level lowers because the water from the ocean gets trapped in the glaciers as ice. The sea level even 10,000 years ago was about 120 meters or about 394 feet lower when compared to the modern sea level. If the Greenland ice sheet of today were to completely melt, for example, that would result in a rise in sea level of about 6 to 7 meters or about 20 to 22 feet. In the case of this study, Beryllium 10 (^{10}Be), which is a radioactive isotope of Beryllium, will be used to determine the dates of when the glacier receded from the areas of study, mainly the Island of Greenland and the Carpathian Mountains in Europe.

Elevation data from Global Positioning System (GPS) readings obtained from perched boulders and glaciated bedrock, combined with ages obtained from ^{10}Be and ^{26}Al dating, will improve the ice thinning rate estimates during the Late Glacial Maximum, which occurred about 13,000 years ago (currently this data is available mostly from glacial models). However, field work and sampling in Greenland was done in 2008, and the main part of my current project incurs the preparation and analysis of collected samples. Also, empirical analyses, previously conducted by this team, suggested higher rates than the ones estimated by current glacial models. Recent studies by other researchers support these estimations. However, the low number of samples and uncertainty associated to surface exposure dating requires additional data sampling and dating, part of which was conducted during this geological expedition in August of 2014.

FIELD WORK IN POLAND

The main objective was to look for glacial sequences in the landscape, the formation of moraines[2], which are accumulation of rock debris (till) carried or deposited by a glacier…which also range in size from blocks to boulders, and identify the accumulation of debris from which samples could be collected. Four different locations, three on the Polish side of the Tatras Mountains, and one on the Slovakian side of the Tatras Mountains, were visited to make identification of boulders from which samples could be taken in the future. Unfortunately, only two of these sites proved to have rocks with adequate size and exposure from which to collect samples that would give accurate readings.

The work in the field involved: The use of GPS recorders to map terminal and lateral moraines, but also potential glacial trimlines; the recording of rock sample characteristics for surface exposure dating; and gathering geographic information, which will be used to develop pedagogical material and create a GIS database of the information gathered. The geographic positions of boulders were recorded (using GPS), in the areas where they were accessible. These areas, where the rocks had less vegetation cover, are the sites which will provide more accurate surface exposure ages. Also, topographic, geologic, and geomorphic maps were used in order to aid in the process of better understanding the areas being explored. The use of these maps, in conjunction with each other, made it easier to find the location of moraines.



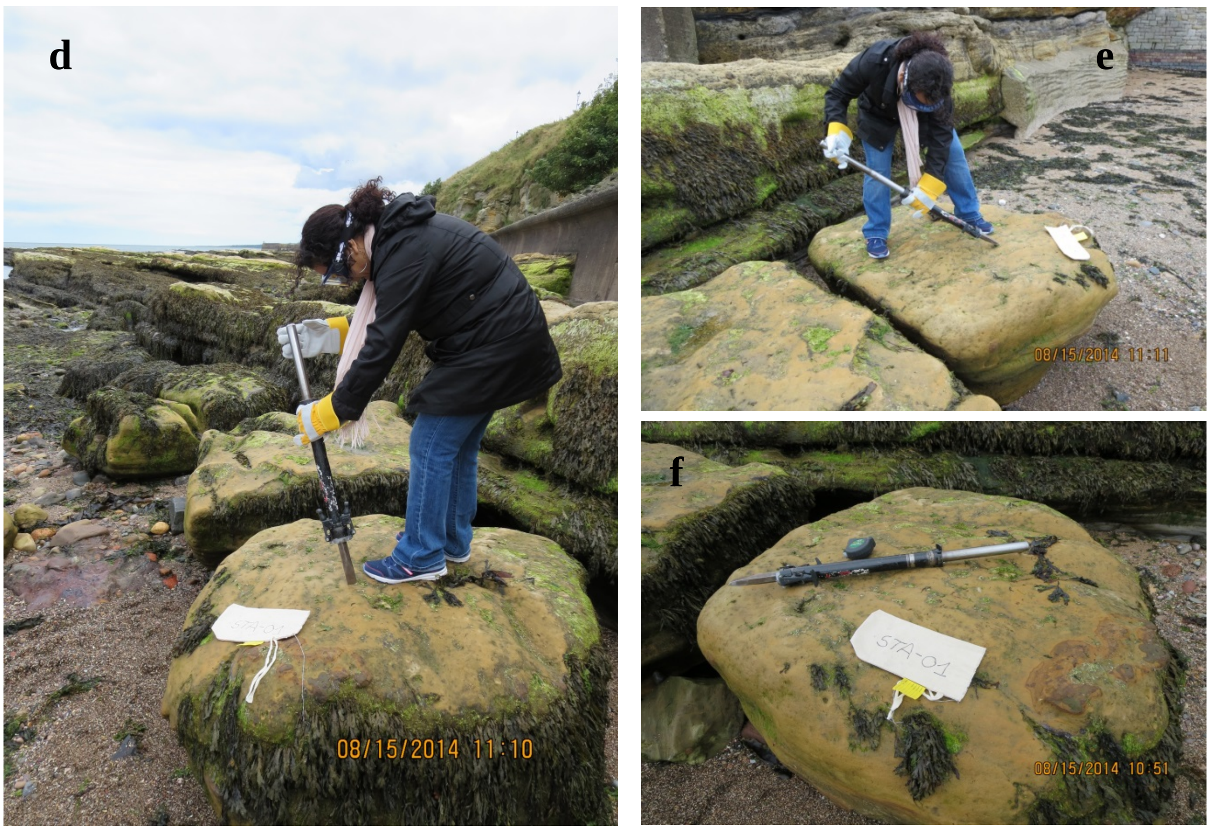
a) Me hiking in the Biala Woda Valley, Tatras Mountains, Poland
b) Exposed Quartz found on a boulder discovered during the hike in the Mala Laka Valley, Tatras Mountains, Poland
c) The view from one of the highest Cirques when hiking the Hincove Pleso, Tratas Mountains, Slovakia

The first exploration took place in the Biala Woda Valley and its surroundings. The hike to this site was long and treacherous. The terrain changed four times along the trail, from dirt to a pebbled road, to a sea of oddly shaped and placed larger rocks, to a muddy slippery slope on the way down after it had rained for about five minutes. The third hike was to Mala Laka Valley, but due to a major storm, which hit that region last year and left fallen trees along most of the paths, it was impossible to reach the areas where the boulders were (in some of the moraines); this terrain too was mostly muddy due to the sporadic showers that fall on the mountain during that time of year, but the terrain was not as steep in Biala Woda Valley. Both these valleys are found on the Polish side of the Tatras Mountains.

However, the last hike became the best hike, which took place on the sixth day where the team hiked to one of the highest lakes of the Tatras, Hincove Pleso, on the Slovakian side of the mountains. Along the path a number of glacial features, crescentic marks and striations on the bedrock from the glacier and places where meltwater had shaped the rock, could be recognized. This hike was also long (it took about eight hours to complete) and was the steepest of all the trails traveled (there were areas along the path where the slope was nearly vertical). Once a suitable and high enough vantage point was reached, the immense U-shaped valley with a moraine in the middle, the hanging valley on the right and the avalanche corridor could be seen. This area had a rich supply of large granite boulders, which were perfect for sampling; mainly due to the material dumped where the glacier had been carrying it, as it melted.

LAB WORK IN SCOTLAND

Unfortunately, the park permits that were acquired did not allow for rock samples to be collected from the hiking sites in the Tatras National Park, which is the part of the Mountains where geological expeditions could be conducted. For this reason, the procedure by which a sample is taken from a boulder was practiced in the Geology Department of the University of St. Andrews. First, the coordinates of where the boulders are located within the moraines must be obtained using maps, a GPS device, and then entered into a geographical information system (if possible). Once the coordinates are obtained, a compass and a clinometer (used for measuring the angle or elevation of slopes) must be used to calculate how much cosmogenic radiation the rock is exposed to. This is done by the measuring of the "shadow" of the rock from its surrounding area. Then a manual jackhammer (among other tools) is used to extract a sample from the rock, in this case it was sandstone. All the data is carefully recorded on a prepared sheet so that when each sample is taken to the lab the information on each of the samples collected is listed in a clear and systematic manner.



d &e) Me demonstrating how to use the manual jackhammer to collect samples form a boulder, St. Andrews, Scotland

f) The manual jackhammer, the compass, and the bag in which a collected sample is stored, on a boulder, St. Andrews, Scotland

Once in the lab, the rock samples that were collected in Greenland, which were previously separated and marked (each ranging from three thousand to five thousand grams), were first crushed in a machine called a Jaw Crusher. This was done to reduce their size that they may be more manageable. The machine first needed to be cleaned with a hard-tooth brush and with compressed air to assure that no contaminants from previous crushed rocks were mixed with the new samples. The newly crushed fragments, for each sample, were collected in a plastic bucket that was also cleaned with compressed air, before being used. Each rock sample was crushed separately; all the rock samples collected were individually packaged and labeled.

The fragments were then transported to a Type UA Pulverizer to be reduced to a grain size fraction; the pulverized material was collected in a metal drawer on the bottom of the machine. The end of the hose of a vacuum cleaner was placed on the outside of this drawer to vacuum up dust debris that would escape through that space. This process was repeated at least four times for each rock sample, until the desired fragment size was obtained. The fragments were poured in from the top of the machine unto the blades that were covered for safety. It is spinning blades that reduce the size of the fragments to tiny particles, even dust. Each time the sample had to be run through the Pulverizer, however, the blades had to be adjusted, brought closer together, to accommodate the decreasing grain size. The grains from the fragments were then poured onto test sieves. They were separated through sifting in three different size test sieves; the first test sieve (the one on top) was seven hundred and ten micrometers and the second sieve (directly underneath it – the middle sieve) was two hundred and fifty micrometers. The material that had to be run through the pulverizer to continue to reduce the size of the fragments was taken from the top sieve; it was transported and poured unto the pulverizer in a small plastic bucket that was cleaned with compressed air before being used.

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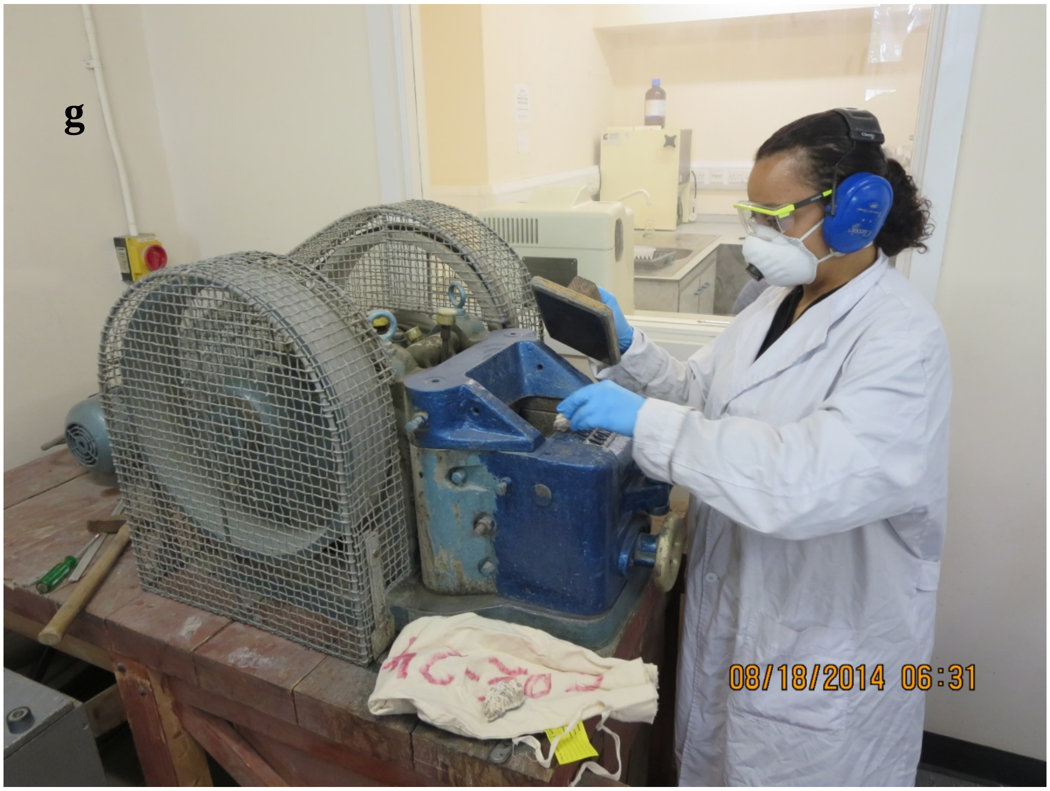

g) Me taking the first step into making the rock samples smaller by crushing the samples with the Jaw Crusher (above).

h) Me taking the second step into making the rock samples smaller by running the crushed samples through the Type UA Pulverizer to pulverize the pieces that were newly crushed (below).

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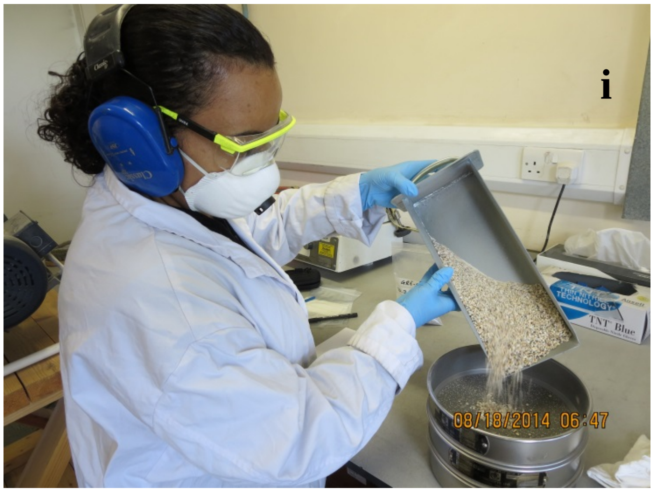

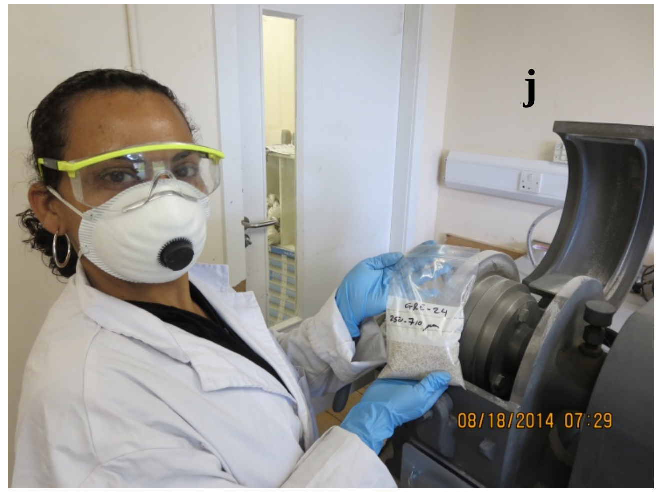

i & j) Me taking the third step into making the rock sample smaller by running the bigger pieces of the sample through the pulverizer multiple times until the entire sample yielded the desired size grain; and shifting the sample in three different sized sieves.

Once all of the fragments have been completely pulverized to the desired size, which should be between two hundred and fifty and seven hundred and ten micrometers, then the material must be separated, the magnetic material from the non-magnetic. Only the non-magnetic material is utilized for testing, meaning the quartz. The material is run through a Frantz isodynamic separator machine, which should yield about three hundred to four hundred grams of non-magnetic material. There is a distinction between the two types of material: The non-magnetic is a lighter material than the magnetic, which is darker. Also, this machine must be precisely calibrated as to not have the magnetic material mix with the non-magnetic. There is a lever on the machine that controls the strength of the vibration of the chute through which the material travels while it is being separated. The mixed material is poured into a funnel and gravity carries it through a split sloped chute that is vibrating. At the same time there is a magnet on one side, which guides the magnetic material away from the non-magnetic as each is collected at the end of the chute into labeled containers. The magnetic contents are discarded, but the non-magnetic are again packaged, in a bag, and labeled.

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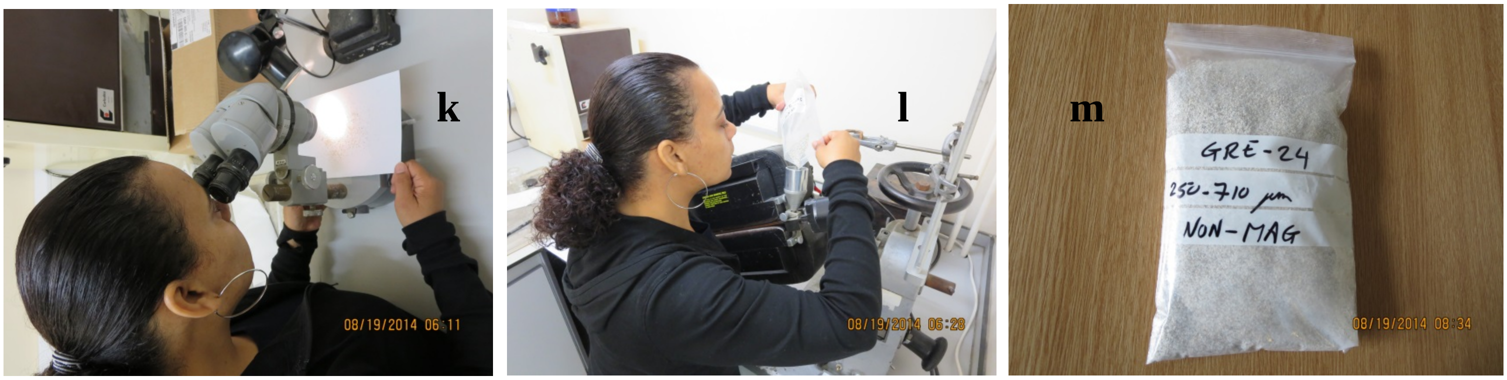

k & l) Me taking the last step into making the rock sample smaller by running the pulverized sample through the Frantz isodynamic separator machine in order to separate the magnetic material from the Non-Magnetic material within the sample.

m) The final product, which is ready for analysis in the wet lab.

RESULTS

While in Poland, readings were taken of both GPS coordinates and geological descriptions of the moraines that were identified. These locations and settings were recorded and marked on maps so that the exact locations could be easily located once the permits are acquired for sampling. The samples, from Greenland, were taken from moraines found while hiking through terraces and cirques, and the same will be done in the Tatras Mountains in Poland and Slovakia. The samples collected in Greenland and the samples that will be collected from the Tatras Mountains will be put through the process of isotope analysis to identify the age of the rocks. In total, five bags of non-magnetic material, of about three hundred to four hundred grams each, were prepared for the next phase of analysis in the wet lab.

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DISCUSSION AND CONCLUSION

Through the use of Geochemistry, and the study of geomorphology methods, it is possible to discover the time hidden in rocks, but it is also possible to learn about and reconstruct the nature of events associated with the time interval. While various dating techniques with inherent accuracies and precisions were used to define the Younger Dryas (11,000 – 13,000 years ago) time frame, these approaches may to some extent have provided the fuel igniting the debate on the synchrony or asynchrony of events globally [3]. The occurrence of a Late-glacial cold event has been recognized in many formerly glaciated regions in Europe and in the rest of the world including the southern hemisphere and the timing of its expression is at the center of an ongoing debate revolving around climatic lead and lag between the northern and southern hemisphere [4]. Using Surface Exposure Dating using ^{10}Be coupled with Geographic Information System the timing and nature of glacial events could be better understood and mapped across the northern hemisphere. However, depending on the region of study, the Palaeoclimatic interpretations are correlations become more and more equivocal [5].

The production rates of cosmogenically produced isotopes such as ^{10}Be are affected by the altitude, latitude and the variation of the geomagnetic field [6]. For this reason this continual field work and research is being conducted by this team. For example, the thinning of the ice sheet in Greenland increases concerns regarding possible and future rise in sea level. In order to appreciate the full extent of its contribution to sea level rise, reconstruction of the ice sheet's most recent last deglaciation could provide key information on the timing and the height of the ice sheet at a time of rapid climate readjustment [7]. Further study is needed to reconstruct the events of the past, in regards to glacial formation and retreat, and the timing of those events in order to better understand what is happening today and possibly what may happen in the future.

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FUTURE WORK

The samples will be then transferred to a wet lab. The process that will take place to determine the age of the samples is as follows: The samples in each bag will be boiled in phosphoric acid for a few hours to eliminate all the aluminum silicate in the rock to purify the quartz as much as possible. Once boiled, the sample is then rinsed and washed, and then leached three times over a period of 24 hours each (a total of 72 hours), in a solution of hydrofluoric acid and nitric acid. This is done, with these low acidic solutions, to remove all traces of Beryllium 10 produced in the atmosphere around the grains that could have penetrated into the crystals through microscopic cracks in the rocks. Once this process is finished the sample is checked for purity using a very small amount, which is ran through an ICP-MS (Inductively coupled plasma mass spectrometry), which is used to detect metals and non-metals all at concentrations as low as one part in 10^{15} (part per quadrillion ppq); though in this case it is used to detect aluminum concentration, which needs to be below 200 ppm in the sample. Then the whole sample is dissolved in pure hydrofluoric acid, and a spike of Beryllium 9 is then added, which is useful with the measurement in the Accelerator mass spectrometry (AMS) analysis. Because Beryllium 10 is produced in such low quantities it is useful to spike Beryllium 9 into a known quantity to be able to get a ratio when the samples are analyzed. Once the sample is completely dissolved it is put through gravity column chromatography; through an anion resin and then a cation to be purified and to separate unwanted isotopes from the sample. Then the sample is placed on a rapid incinerator to allow for further unwanted isotopes to evaporate out of the solution. What should be left are a few micrograms of Beryllium Oxide (about 0.2 grams). This final product is what will be tested and analyzed to determine the age of the rocks from which the samples were taken.

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