12-20-2018

Micromechanical Characterization of Westerly Granite

Katharine Padilla
Washington University in St. Louis

Kathy Flores
Washington University in St. Louis

MICROMECHANICAL CHARACTERIZATION OF WESTERLY GRANITE

Katharine Padilla

Washington University in St. Louis
PI: Katharine Flores, MEMS

Introduction

The purpose of this research is to perform micromechanical testing of abundant minerals found in the crust and upper mantle of the earth to better understand their material properties. Large-scale deformation studies of rocks are commonly conducted at high temperatures and under large confining pressures, simulating the conditions found in the mantle, to prevent cracking and promote plastic deformation. However, such testing provides limited insight into the local deformation processes occurring at the atomic level, and repeated testing to achieve statistically significant results can be challenging. In this research, nanoindentation methods will be used to characterize the local plastic deformation behavior of Westerly Granite at low temperatures. By pressing a small pyramidal indenter into the rock’s surface at positions of interest, we can probe variations in properties over micron length scales, while the undeformed material surrounding the indent provides a natural constraint against crack formation and growth. This approach can gather information about the hardness and yield strength of the rock in a broader range of temperatures than what has previously been accomplished. As this process is used on this and other abundant Earth materials, a greater understanding of their material properties will allow for an increased comprehension of mountain formation and plate tectonics that could potentially be used to predict their behaviors and explain natural phenomena.

Westerly granite is composed of quartz and two types of felspar, orthoclase and plagioclase. The composition of westerly granite allows for a way to quickly characterize multiple phases and orientations at once. These results can be compared to previously published results to learn more about their nature. Additionally, experiments for Westerly granite can investigate for anisotropy performing indentation test.

Procedure

A 1x1 cm sample of Westerly Granite was sectioned from a parent piece with a 1 mm thickness. The sample was polished through a series of various grit size silicon carbide paper and diamond paste, finished with a colloidal silica solution. Scratches on the sample surface were minimized to expose the microstructure.

Experimentation

EBSD

Phases of the granite sample were characterized using EBSD. Imaging was done on two separate occasions due to issues with the microscope. Images were cleaned post processing. The full EBSD map is shown in Fig. 1.

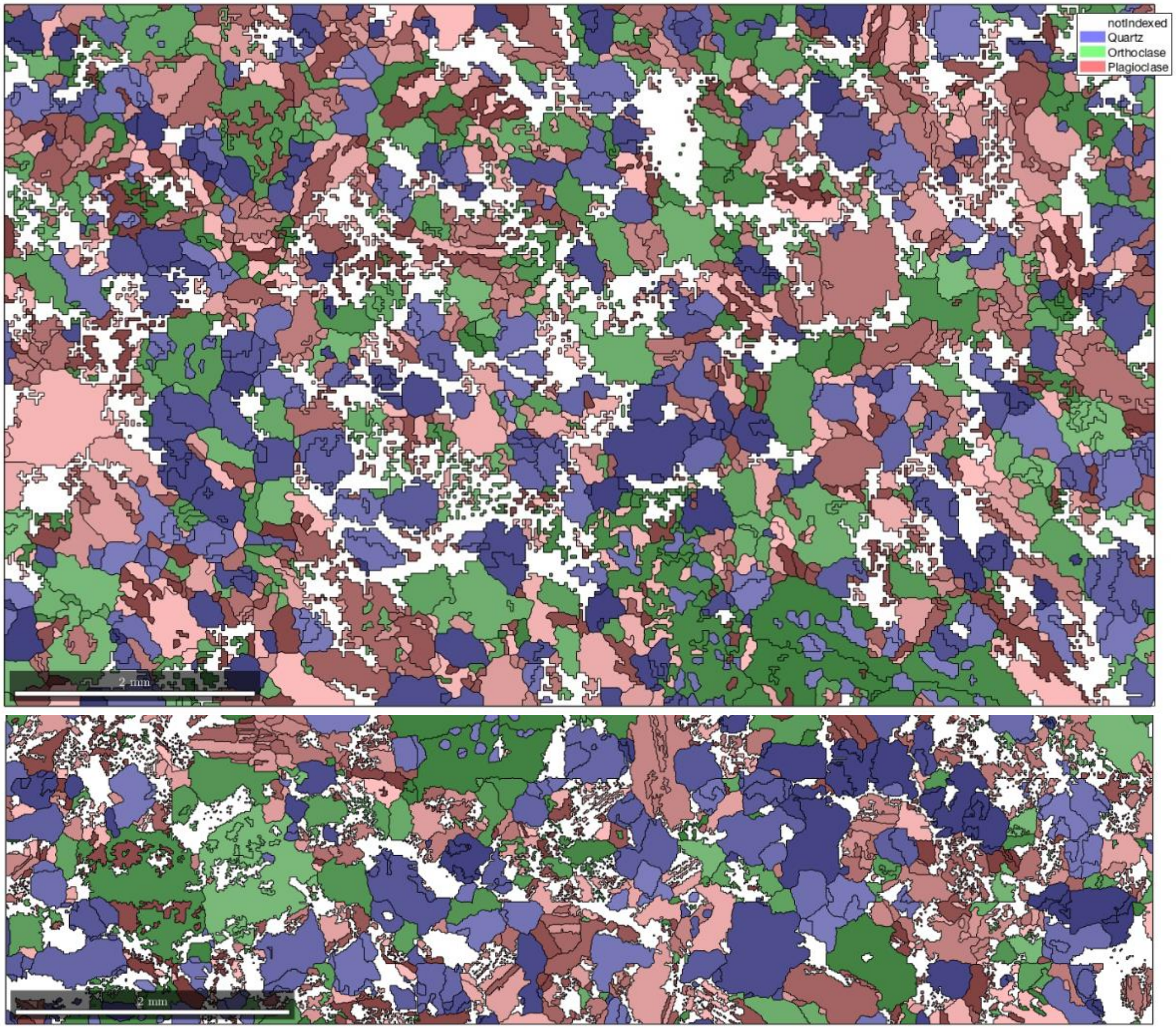

Figure 1 *EBSD map of Westerly Granite sample.*

Phase orientations were analyzed and identified using MatLab. The orientation maps are shown in Fig. 2, 3, and 4.

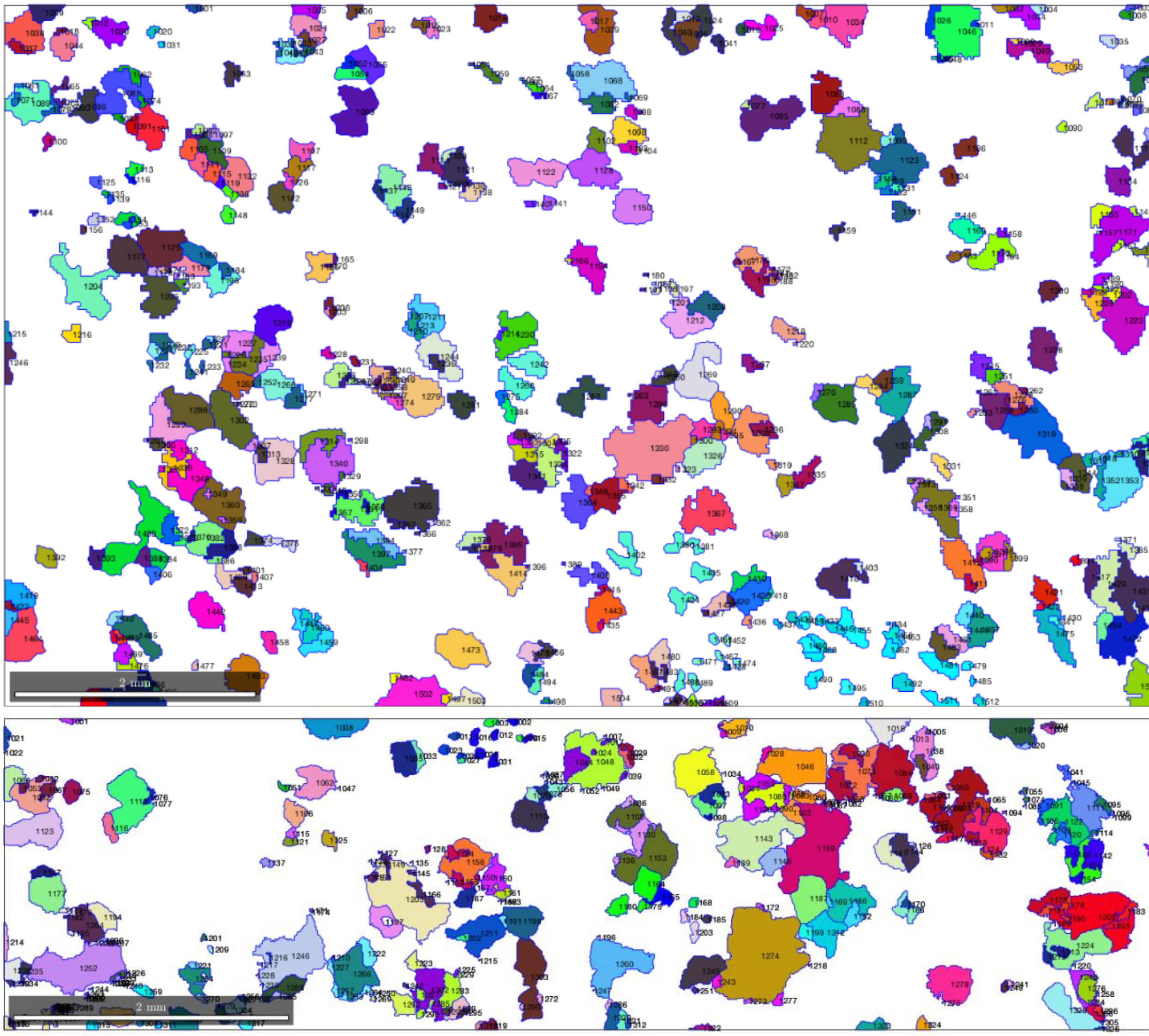

Figure 2 *Orientation map of quartz grains within Westerly Granite sample.*

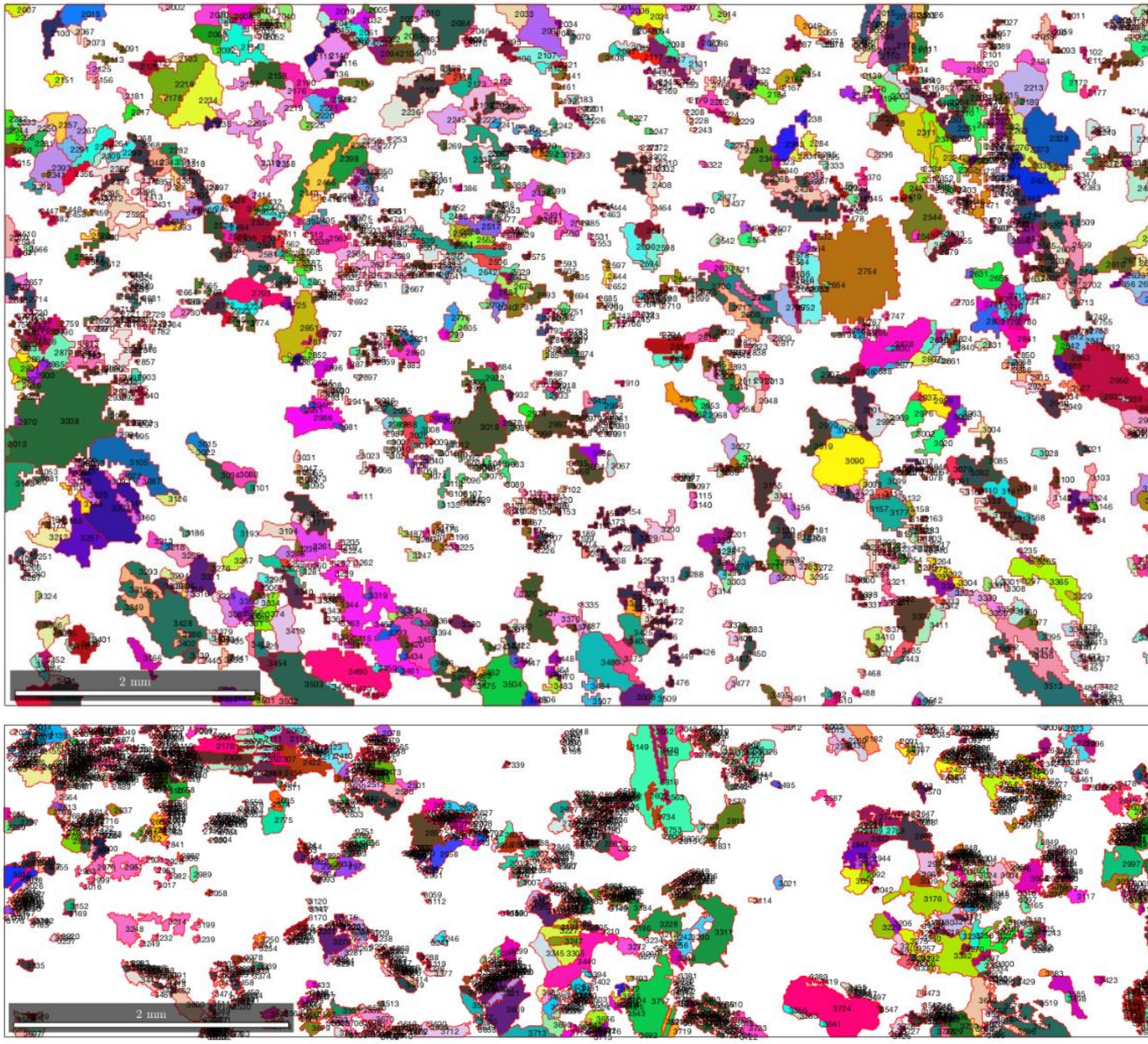

Figure 3 *Orientation map of plagioclase grains within Westerly Granite sample.*

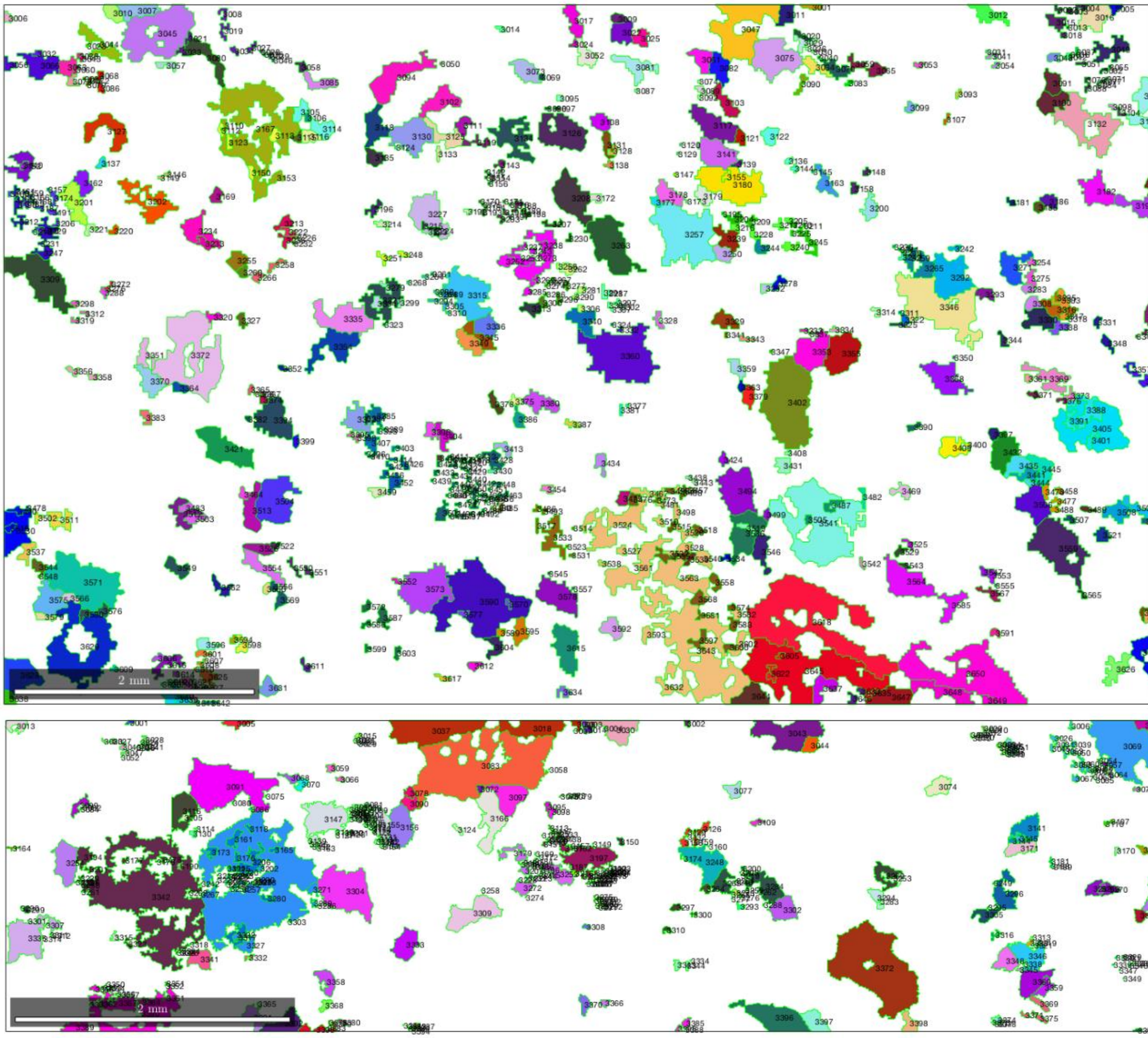

Figure 4 *Orientation map of orthoclase grains within Westerly Granite sample.*

Indentation

Indentations were conducted on a Hysitron nanoindentor at room temperature (23 ˚C), with an applied max load of 8000 µN. A 21x21 array of points was created for a total of 441 points. Hardness and elastic modulus for each point was plotted as a function of its position. A total of four areas were tested, three of which are shown in Fig. 5, 6, and 7.

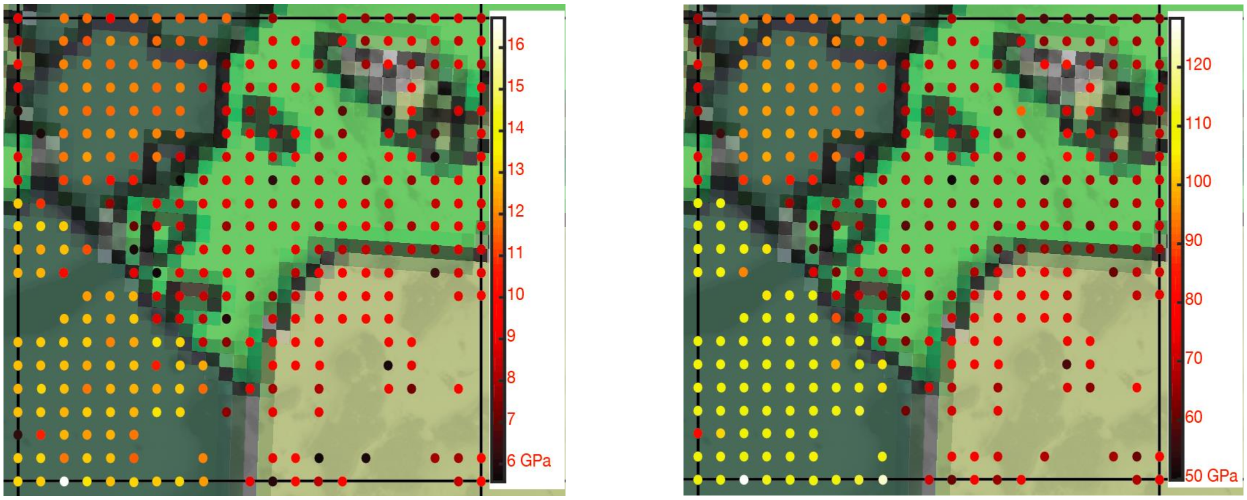

Figure 5 *Hardness (left) and elastic modulus (right) of 21x21 indentation array area with 10 µm spacing.*

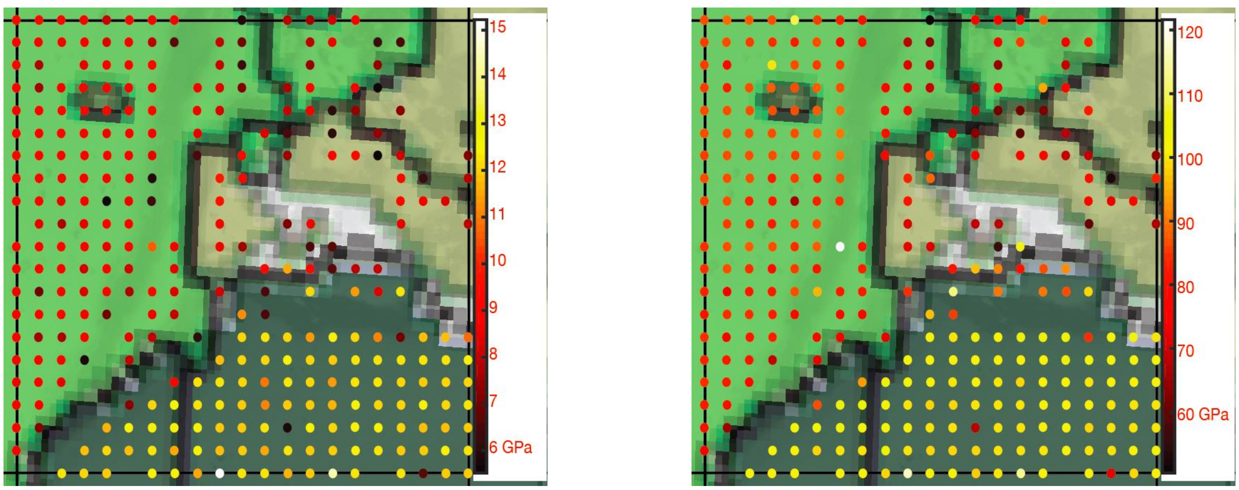

Figure 6 *Hardness (left) and elastic modulus (right) of a different 21x21 indentation array area with 10 µm spacing.*

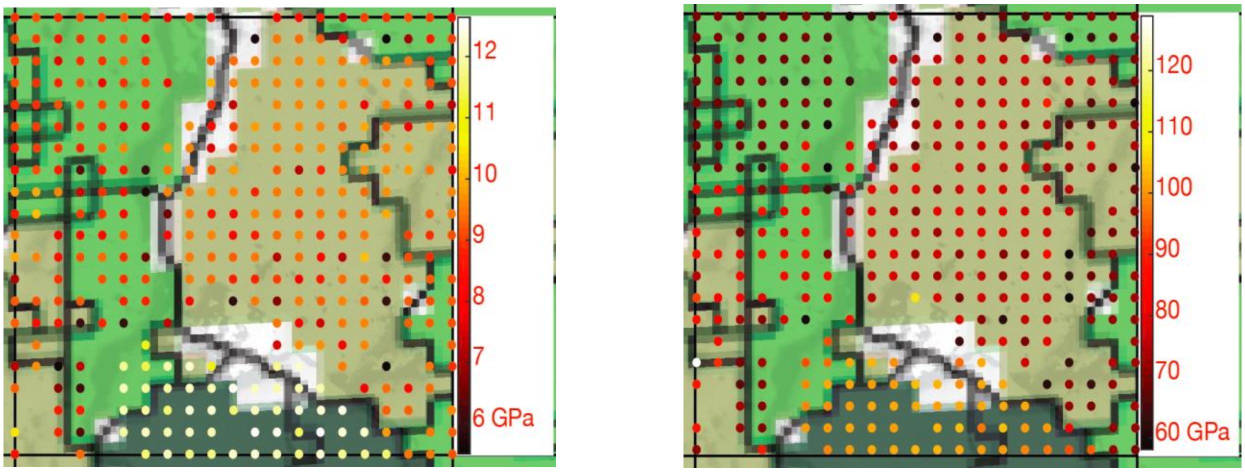

Figure 7 Hardness (left) and elastic modulus (right) of 21x21 indentation array area with 20 µm spacing.

Results

Data for all grains was separated and sorted according to phase. The average measured hardness was plotted against the average elastic modulus for each grain and separated into plots by phase (see Fig. 8, 10, and 12). Orientations for each grain were plotted on pole figures (see Fig. 9, 11, 13). The plots were compared for possible anisotropic effects within the material.

Quartz

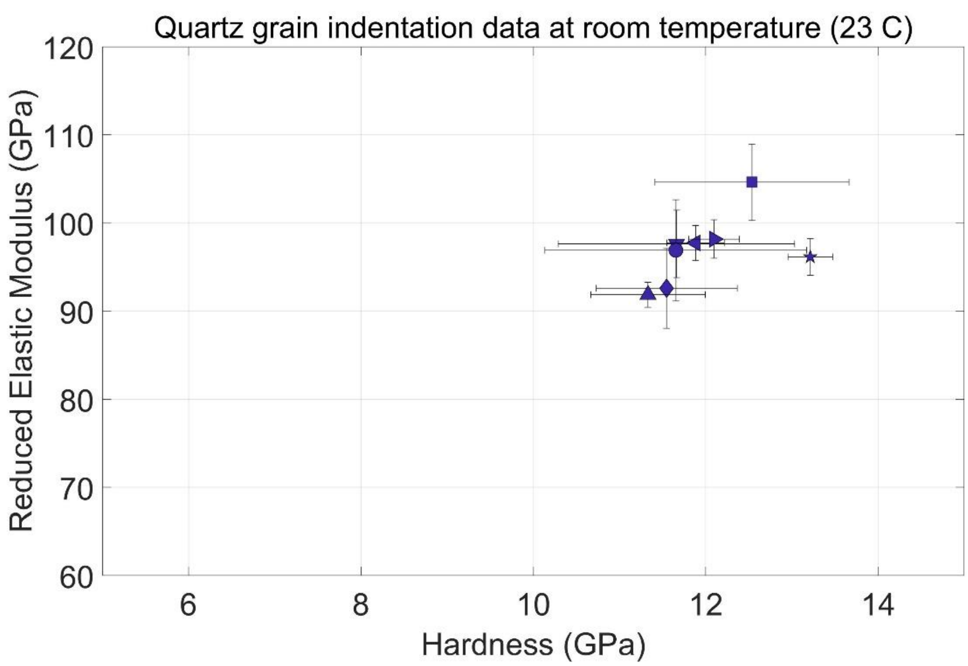

Figure 8 Average elastic modulus vs. average hardness for all quartz grains tested at room temperature.

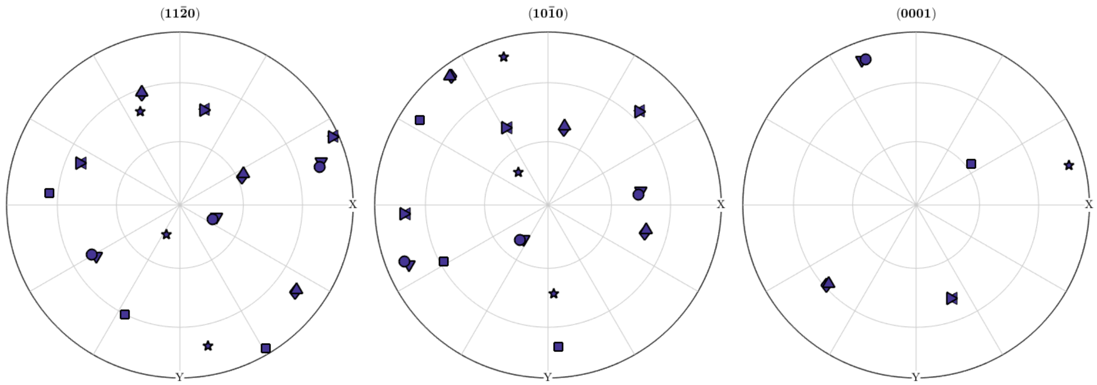

Figure 9 *Orientations of individual quartz grains tested at room temperature. Shapes correspond to points on previous plot.*

Plagioclase

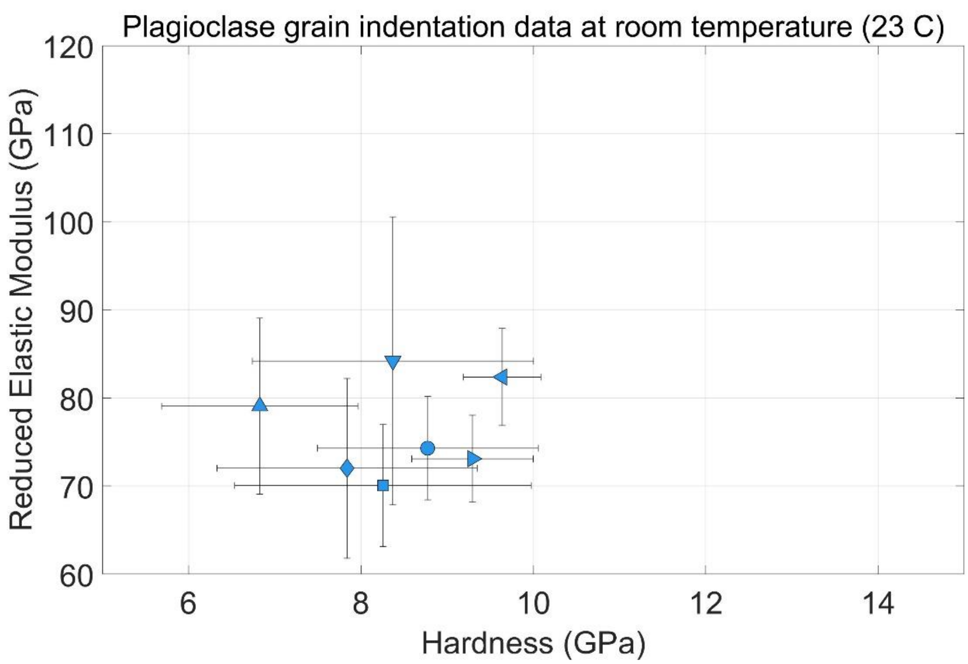

Figure 10 *Average elastic modulus vs. average hardness for all plagioclase grains tested at room temperature.*

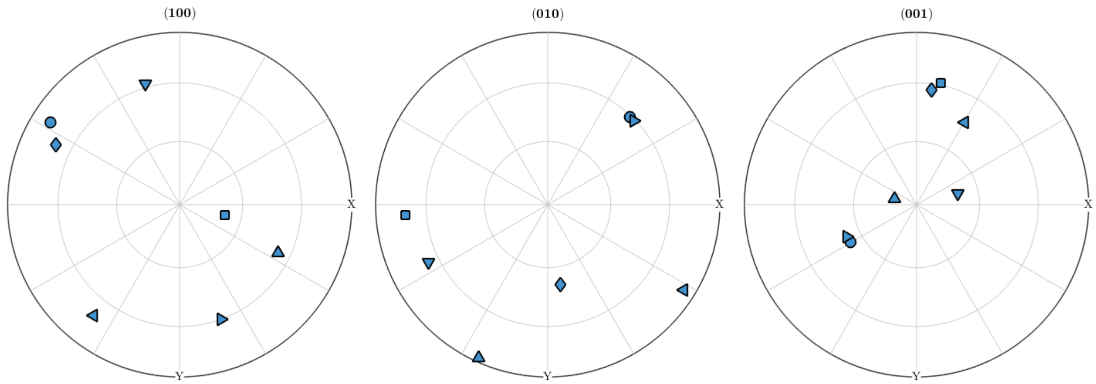

Figure 11 *Orientations of individual plagioclase grains tested at room temperature. Shapes correspond to points on previous plot.*

Orthoclase

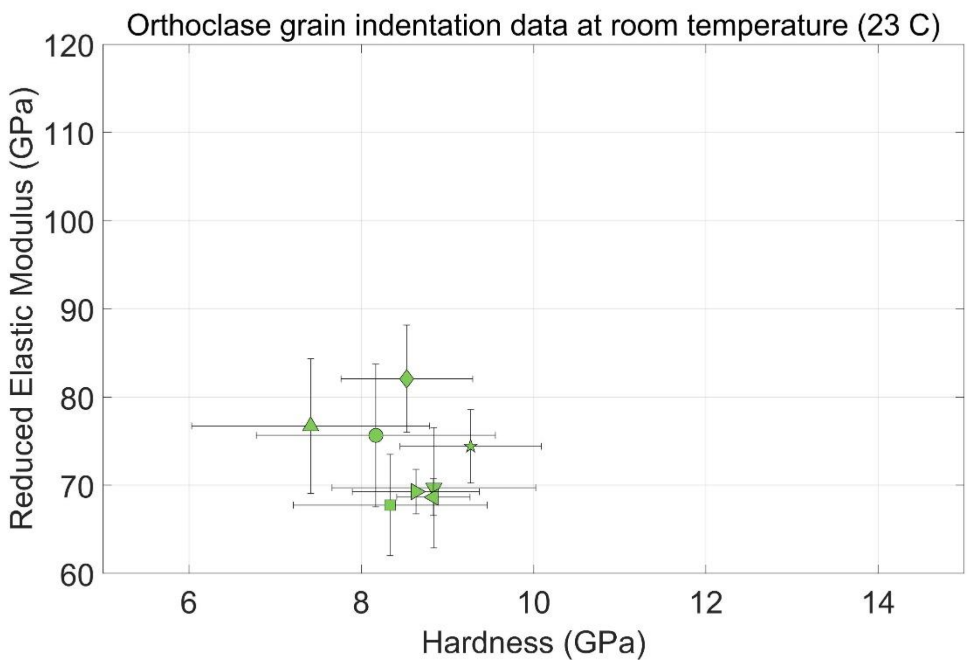

Figure 12 *Average elastic modulus vs. average hardness for all orthoclase grains tested at room temperature.*

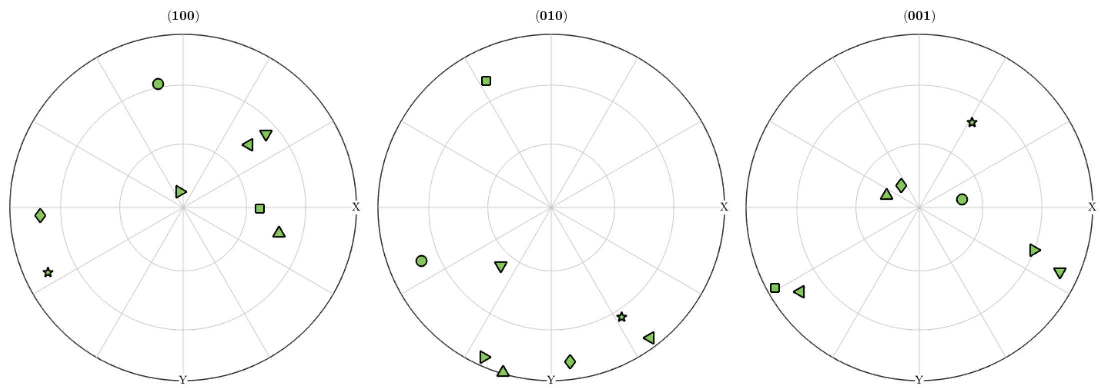

Figure 13 Orientations of individual orthoclase grains tested at room temperature. Shapes correspond to points on previous plot.

Conclusion

Anisotropy was seen between the quartz grains that were tested, however no noticeable difference could be made for the feldspar grains. More points might be needed for the feldspar grains to make a conclusive decision. Additionally, high temperature tests have been started to see the affect temperature has on the material and respective properties of each grain. From these future tests, more information about the anisotropic nature of Westerly Granite is hoped to be discovered.