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MINERALOGICAL COMPOSITION OF DIABASE AND ALTERED DOLOSTONE FROM THE ST. FRANCOIS MOUNTAINS NEAR ANNAPOLIS, MISSOURI, USA

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ABSTRACT

Dolostones of Cambrian and Ordovician age are found in the St. Francois Mountains on the Ozark Plateau in southeastern Missouri and often lie unconformably over Precambrian basement rocks due to the paleo-topography. In some areas, there is distinct evidence of alteration and mineralization within the dolostones. One such location is found near Annapolis, Missouri where nearly all of the original dolomitic material is replaced with quartz. A diabase dike is in close proximity to the silicified dolostone and may have provided the conduit for fluids during alteration. The purpose of this study was to examine samples from the relatively unaltered dolostone, the silicified dolostone, and the diabase in order to establish the mineral changes associated with the alteration. Several samples were collected and analyzed in hand sample, in thin section, and using X-Ray Diffraction. In the diabase, plagioclase was abundant in both hand sample and thin section. The XRD results confirmed the presence of plagioclase as labradorite and supported evidence of magnetite as well. The highly altered dolostone exhibited original sedimentary laminations and varied in color. In thin section, the altered dolostone was very fine grained and the minerals that appeared to be present were quartz and an opaque mineral. After XRD analysis it was concluded that quartz was present and a pyrite structured sulfide mineral was present as well. The other four samples were dolomitic with laminations that varied in color from dark red to cream. XRD results indicated that dolomite, ankerite, and minrecordite were present in the dolostone.

KEY WORDS: St. Francois Mountains, Cambrian, Ordovician, x-ray diffraction, diabase, dolostone

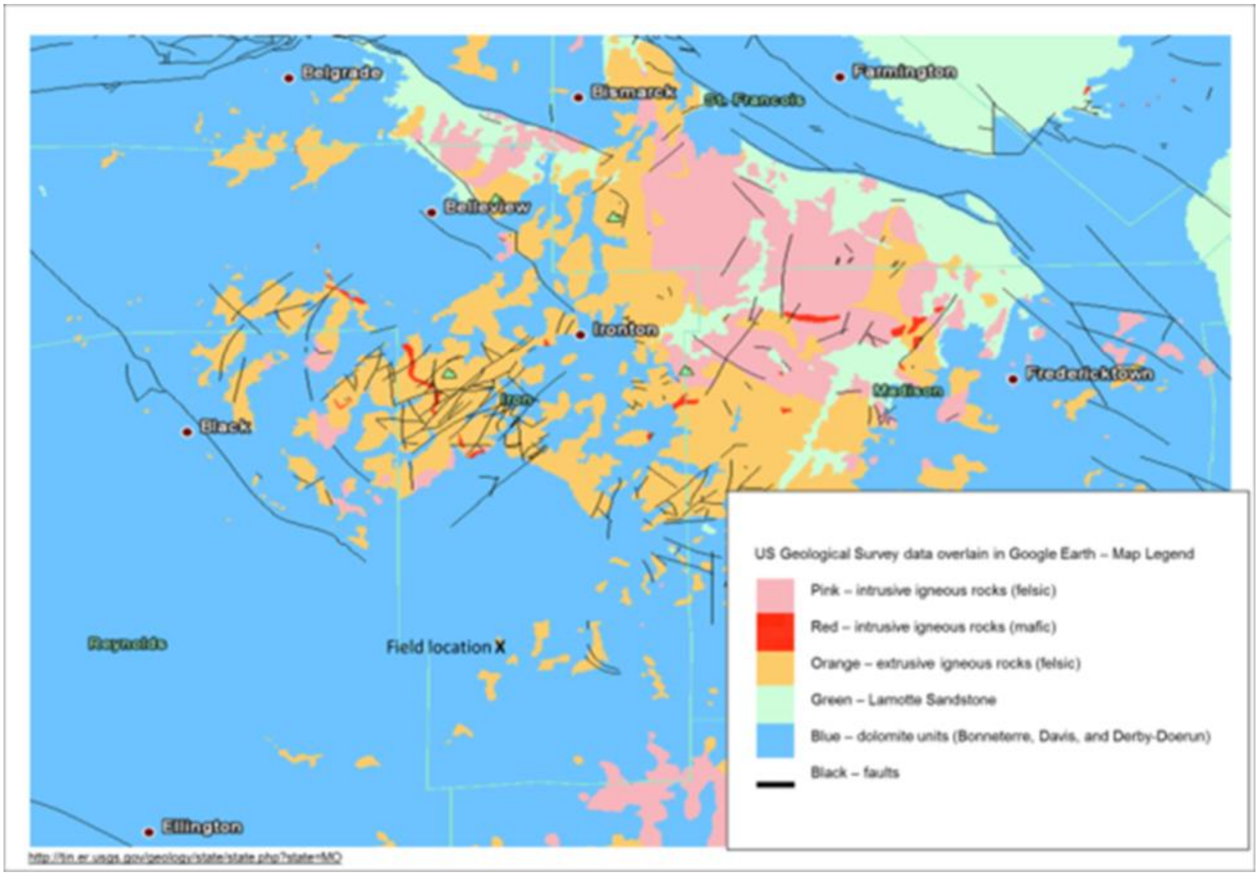

Figure 1. Geologic map of the study area.

INTRODUCTION

The purpose of this undergraduate research project was to determine the mineralogical changes associated with silicification of dolomitic limestone (dolostone) by analyzing the minerals contained within the silicified dolostone, the normal dolostone material, and the mineral composition of the diabase dike. After determining the minerals contained within these samples, the next step will be to identify the link between the diabase and the dolostone found in the St. Francois Mountains on the Ozark Plateau of Missouri.

The geology of the St. Francois Mountains in southeast Missouri is dominated by the Precambrian volcanic and associated plutonic terrane (fig. 1). These volcanic and plutonic rocks were formed at approximately 1470 ± 30 Ma (VanSchmus, *et al.*, 1996) and continue into the subsurface of the surrounding region. Volcanic rocks in the region have been interpreted as forming from large calderas and many of the associated granitic plutons are recognized as ring plutons (Kisvarsanyi, 1981). Subsequent igneous activity is evident in the younger Graniteville granite at ca. 1370 Ma (Thomas, *et al.*, 1984) and from the mafic intrusive bodies as dikes and sills within the region. These igneous rocks have been exposed as a result of the Ozark uplift and the associated geologic structures.

Sedimentary rocks were deposited around and over the basement rocks during the early Cambrian resulting in the Lamotte Sandstone and Bonneterre Dolomite (dolostone). The Lamotte Sandstone ranges in composition including feldspathic, lithic, and quartz arenites that are interpreted as detritus from the volcanic and plutonic rocks of the Precambrian basement in the area (Houseknecht and Ethridge, 1978). The Lamotte Sandstone varies in thickness as controlled by the topographic surface of the basement rocks and in places pinches out against the Precambrian knobs where the younger Bonneterre Dolomite is in direct contact with the igneous rocks (Shelton, *et al.*, 1992). There are a series of facies changes evident in the Bonneterre Dolomite including back reef, reef, and offshore as extending north and west from the Precambrian exposures. At least two episodes of dolomitization have been recognized within the Bonneterre Dolomite suggesting fluid flow most likely through the Lamotte Sandstone and into the Bonneterre Dolomite (Gregg, *et al.*, 1992). This fluid flow has also been linked to the Pb-Zn-Cu mineralization in the area (Gregg and Shelton, 1989).

METHODS

Hand Sample Analysis

Hand sample analysis was done using a binocular scope, the Munsell color chart, and hydrochloric acid (HCL). Sample grain size and texture were examined both by the naked eye and under a binocular scope. The scope was also used to detect effervescence in closer detail. The Munsell color chart was used to determined sample color more accurately.

Thin Section Analysis

Thin sections were made from selected samples collected from the St. Francois Mountains area. The minerals were determined using thin section analysis. The thin sections were viewed at 40x and 100x in both plain and cross polarized light (PPL and XPL). In PPL mineral textures, cleavage lines, fracture lines, and laminations were observed. In XPL interference colors, extinction, opaque minerals, halos, and mineral habit were observed. (figs. 2a-j)

Figure 2a. Thin section of diabase in Cross Polarized Light (XPL) at 40x displaying plagioclase crystals.

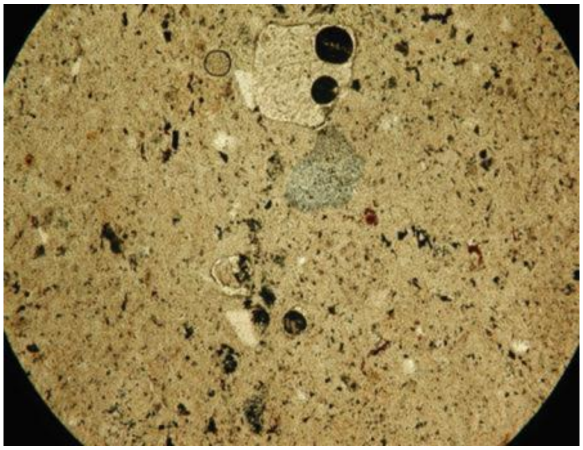

Figure 2b. Thin section of altered dolomite in Plain Polarized Light (PPL) at 100x displays fine grains. Displays two circular black opaque crystals encased in a larger crystal and white crystals visible in fine grained mass. Laminations are visible as well as changes in grain size.

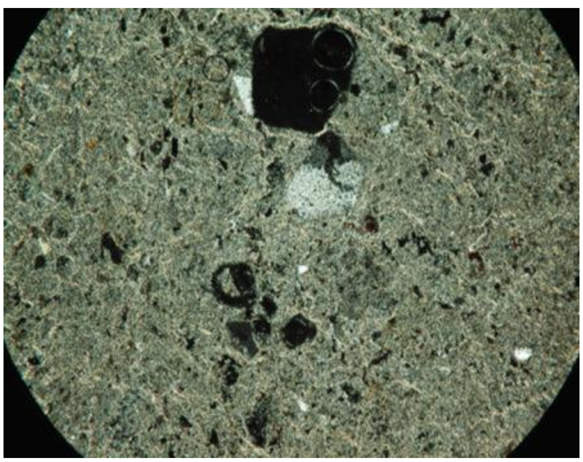

Figure 2c. Thin section of altered dolostone in XPL at 100x shows the black opaque crystals encased in a larger crystal which is displaying extinction. White crystals are still visible in fine grained mass and do not display extinction when stage is rotated.

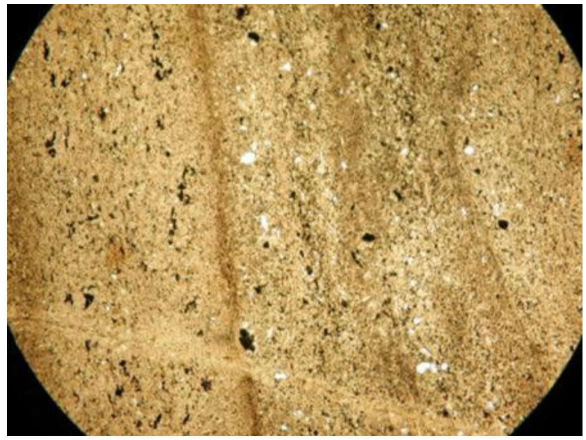

Figure 2d. Thin section of altered dolostone in PPL at 40X displaying laminations and differences in grain size.

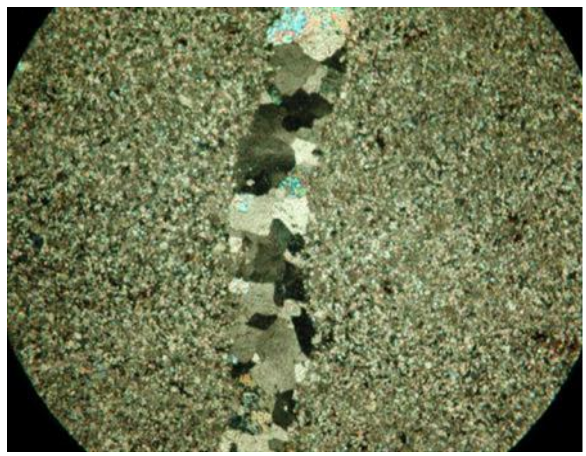

Figure 2e. Thin section of dolostone in XPL at 40X displaying one of the coarse grained veins found throughout the dolomite samples.

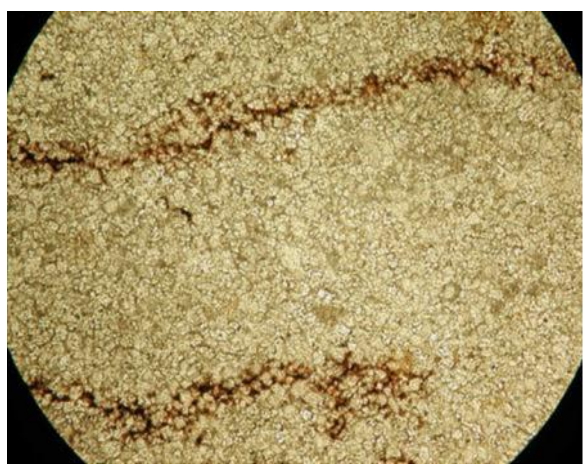

Figure 2f. Thin section of dolostone in PPL at 100x displaying increased dark to opaque minerals along laminations.

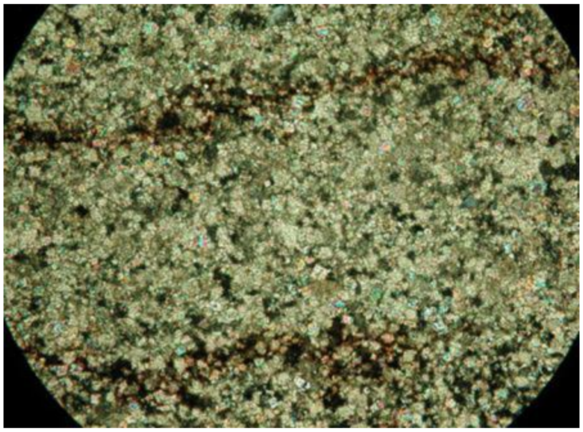

Figure 2g. Thin section of dolostone in XPL at 100x displaying increased dark to opaque minerals along laminations.

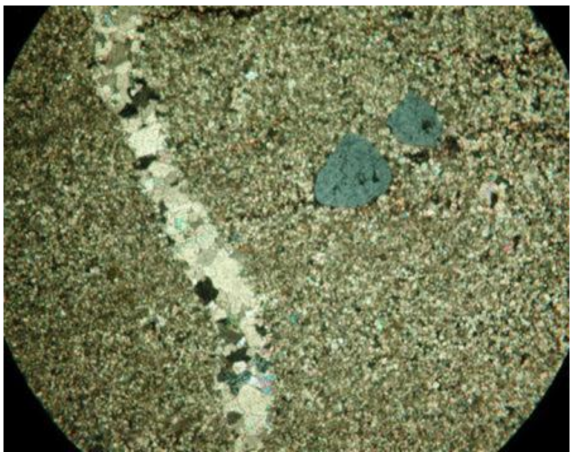

Figure 2h. Thin section of dolostone in XPL at 40X displaying another coarse grained vein that was seen in hand sample. To the right of the vein two large gray crystals were found that display extinction.

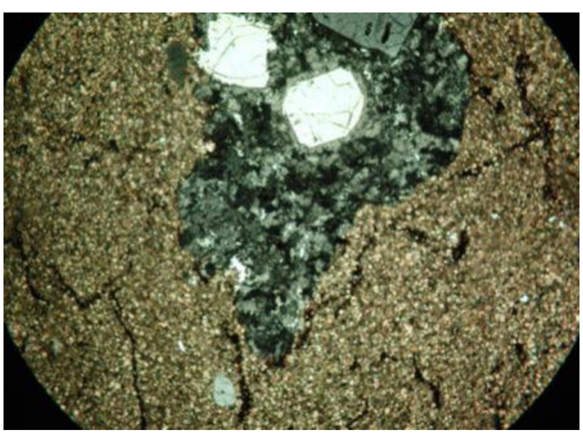

Figure 2i. Thin section of dolostone in XPL at 40X that contains a large mass of finer crystals encasing three larger crystals. The three larger crystals appear to have a well-defined shape and fracture lines.

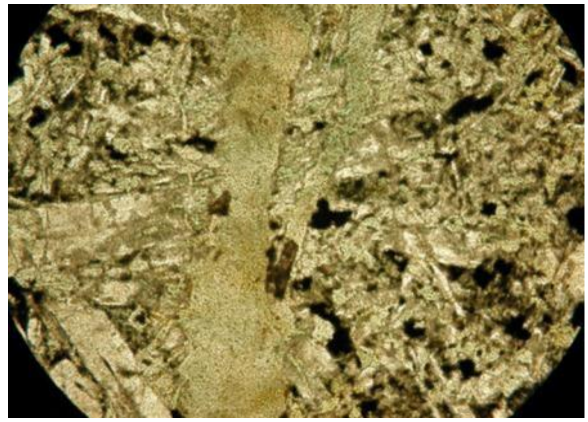

Figure 2j. Thin section of diabase in PPL at 100x displaying one of the green veins found in thin section.

XRD Analysis

Smaller representative samples of the collected rocks were crushed to a grain size of < 63µ. The crushed samples were then run on the Miniflex X-Ray Diffractometer. The scan speed was set at 3° per minute. Our starting angle was at 5° and our stopping angle was at 70° with sampling at 0.10° intervals. Ten samples were prepared for this analysis including two diabase samples, one altered dolomite sample and five dolomite samples. The resulting data was refined by removing the background noise and kα2 (fig. 3, a-c).

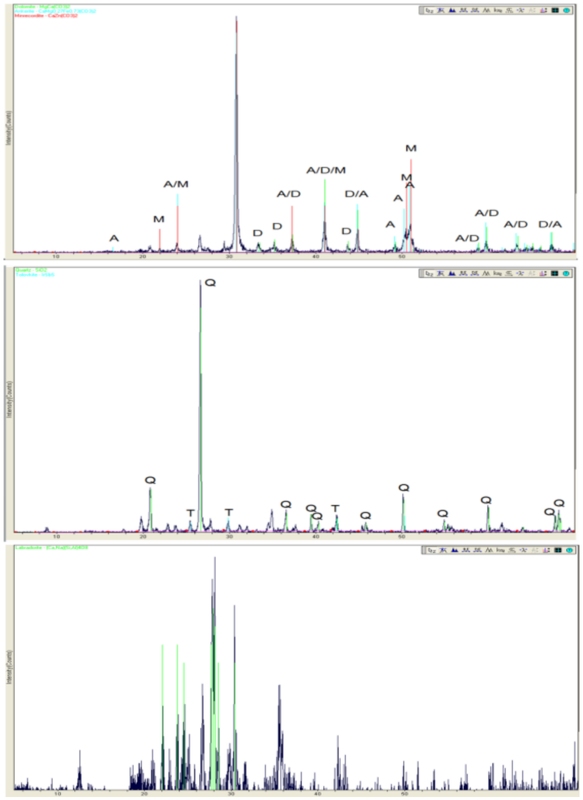

Figure 3, a-c. X-ray diffraction patterns. **(a)** Diffraction pattern from unaltered dolomite sample. Mineral matches include dolomite, ankerite, and minrecordite. **(b)** Diffraction pattern from silicified dolomite sample. Primary peaks are associated with quartz while the secondary peaks are statistically matched with tolovkite. **(c)** Diffraction pattern from diabase intrusion. Although this sample has a high degree of noise, the primary mineral has been identified as the labradorite variety of plagioclase.

RESULTS

Rock Descriptions

Sample SF AN 1A (fig. 4) is a diabase, dark to sparkly gray in color with a slight green tint (Munsell color notation of 3/N, very dark gray). The lighter colored minerals in the sample appeared to effervesce in hydrochloric acid (HCl) under the microscope. The texture is fine grained and has a rough feel. The weathered surface had some dark brown coloring (Munsell color notation of 3/1 10Y, dark greenish gray). The texture of the dark brown surface felt smooth and was fine grained. The weathered portion of the rock did not effervesce in HCl.

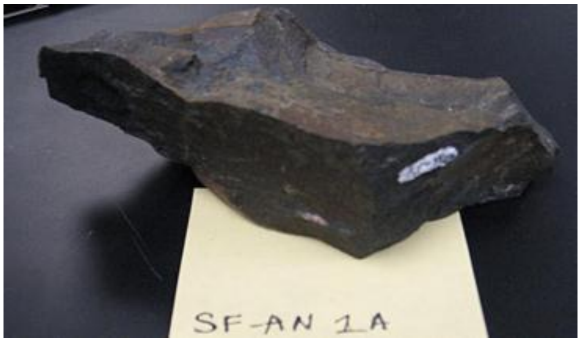

Figure 4. Diabase sample, SF AN 1A.

Sample SF AN 2A (fig. 5) is an altered dolostone. The sample has ~2mm thick laminations that varied in color from light purple, (Munsell color notation of 6/1 2.5 YR, reddish gray) to light pink, (Munsell color notation of 5/3 2.5 YR, reddish brown) to light yellow, to dark red. The sample contained light yellow/cream veins that contained white crystals in the center of the veins. The sample is fine grained.

Figure 5. Altered dolostone sample, SF AN 2A.

Sample SF AN 2B (fig. 6) is an altered dolostone. The smooth surfaces of this sample are light purple in color (Munsell color 5/1 10 R, reddish gray and light pink, and 6/3 2.5 YR, light reddish brown). The rough surfaces are dark pink/gray in color (Munsell color 5/2 2.5 YR, weak red). The mineral grains could not be distinguished with the naked eye or microscope. The sample does not effervesce.

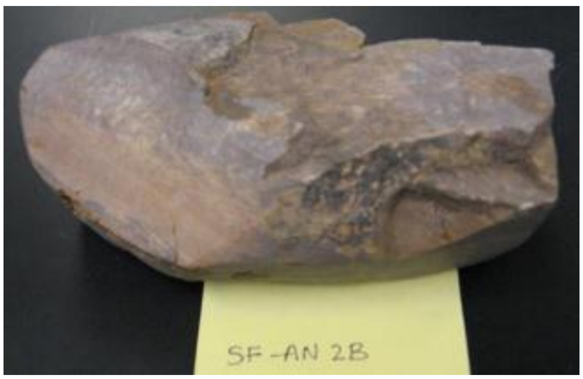

Figure 6. Dolostone sample, SF AN 2B.

Sample SF AN 3A is a dolostone. The sample contained laminations that were about 2mm thick and varied in color from dark red, to light red, to yellow/cream colored veins that contained white crystals in the center. The white crystals effervesced rapidly under the microscope. The rough part of the sample felt like sandpaper and did not effervesce in HCL. The cut surface of the sample did effervesce in HCL. Some of the grains could be distinguished under the microscope. The darker red portion had a Munsell color of 5/4 2.5 YR, reddish brown. The yellow portion had a Munsell color of 8/4 10 YR, very pale brown.

Sample SF AN 4A was a dolostone. This sample had distinct dendrites growing from the white crystals found occurring in the center of the light yellow/cream veins found throughout the sample. Most of the rock was dark red in color with a Munsell color notation of 4/4 2.5 YR, reddish brown. It contained laminations about 2mm thick varying on color. There were white crystals on a broken portion of the rock that appeared to be the same type of crystals as the crystals found in the center of the yellow/cream veins. The crystals in the center of the veins did not effervesce in HCL and neither did the red portion of the sample. This sample had a dusty sandpaper feel.

Thin Section Analysis

Eight thin sections were made from samples collected near Annapolis, Missouri. Two of the thin sections were diabase. In plain polarized light (PPL) one sample of the diabase displayed fibrous green veins. The extinction in the green veins appears to begin on the outer edge and moves toward the center. Some parts of the veins appear to be bluish/gray in color. Both thin sections appeared to contain plagioclase crystals and some small opaque black crystals. Some of the black crystals were octahedral. In cross polarized light (XPL) the larger white crystals displayed a variety of interference colors. The crystals thought to be plagioclase in PPL displayed Carlsbad twinning. The plagioclase crystals also display 90 degree cleavage lines. One of the diabase samples displayed some orange/red/brown crystals that were contained within larger crystals; these appeared to have low relief.

Two of the thin sections made were of altered dolomite. One of these thin sections was stained. In PPL the mass was fine grained. The stained slide displayed some black opaque crystals and some larger white crystals. The unstained slide displayed some small red crystals. Both thin sections showed appearance of laminations and changes in grain size. In XPL the white crystals stayed white and did not display extinction. In both slides a larger crystal was found that contained two circular black crystals that were black in both PPL and XPL. The larger crystal these were contained in was white in PPL and displayed extinction in XPL.

Four of the thin sections made were of dolomite. Many of these thin sections appeared fined grained and contained veins of larger coarse grained crystals. Some of the slides displayed smaller dark to opaque minerals that were found along the laminations. In XPL the veins displayed sweeping extinction and some cleavage lines were visible. One of the thin sections contained a large mass of small crystals that encased three larger crystals. The three larger crystals displayed fraction lines and were euhedral. (fig. 1, a-j)

X-Ray Diffraction

Peak analyses were completed on the powder diffraction files in order to identify the peaks and interpret the data. Jade 8 is a program that is used with in conjunction with the XRD machine. This software interprets the peaks and peak intensities in the patterns. Another interpretative function of the software is to analyze the 2 Theta angle which corresponds to the d-spacing in the pattern results (Figure 3). The peak analysis and statistical match indicated the occurrence of labradorite in the diabase. (fig. 3c.), dolomite, ankerite, and minrecordite in the dolomite, and quartz and tolovkite in the altered dolomite. (fig. 3a-b). Although tolovkite is unlikely, the structure may be similar to another sulfide mineral that may be present as an opaque mineral in our samples. (fig. 3, a-c)

DISCUSSION

The silicification of the dolomite to quartz in this area could be due to hydrothermal alteration. Supporting evidence from another study suggests infiltration of silicate fluids lead to the silicification of dolomite to forsterite. This study was done on the Twin Lakes pendant, in central Sierra Nevada, California. In this area it is believed that contact metamorphism occurred do to the intrusion of the Mount Givens and Dinkey Creek granodiorites. Because of this contact metamorphism, infiltration occurred causing dolomite to silicify and form forsterite. A vein like structure was found that contained a small quantity of quartz. This vein was in direct contact with the dolomite marble that was found in the area which has not been silicified. Between the forsterite vein and the dolomite marble is a scarped surfaces which is an indicator of infiltration of dolomite marble by silicate fluids. (Ferry, *et al.*, 2011) All though our study does not involve forsterite, it does display high amounts of silica.

CONCLUSIONS

There are three distinctly different rock types at the location including diabase, silicified dolostone, and crystalline dolostone. The XRD interpretations provide some evidence of hydrothermal alteration with quartz being the primary mineral in the altered dolomite and the lack of any carbonate minerals. Initial review of the XRF data is supportive of the major elements that would go along with the rock type. Additional data calibration is needed for further conclusions.

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