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DISCRIMINATION OF ALKALINITY IN GRANITOID ROCKS: A POTENTIAL TIMS APPLICATION

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1. INTRODUCTION

In mineral exploration, the ability to distinguish and map petrochemical variations of magmatic rocks can be a useful reconnaissance tool (e.g., Keith, 1986). Alkalinity is one such petrochemical parameter and is used in the characterization of granitoid rocks. In quartz normative plutonic rocks, alkalinity is related to the composition and abundance of feldspars. Together with quartz abundance, knowledge of feldspar modes allows the classification of these igneous rocks according to the Streckeisen diagram (Streckeisen, 1976). Alternative classification schemes rely on whole rock geochemistry instead of mineral identification. The relative ease of obtaining whole rock analyses means that geochemical classifications tend to be favored in exploration geology. But the technique of thermal infrared spectroscopy of rocks yields information on mineralogy and is one that can be applied remotely. The goal of the current work then is to establish whether data from TIMS can be used to distinguish the mineralogical variations that relate to alkalinity.

An ideal opportunity to test this thesis arises from the work presented in a paper by DeWitt (1989). This paper contains the results of mapping and analysis of Proterozoic plutonic rocks in north-central Arizona. The map resulting from this work delineates plutons according to alkalinity in an effort to establish a trend or polarity in the regional magmatism. Also contained within this paper are brief descriptions of the mineralogy of half of the region's plutons. This combination of mineralogical and geochemical information was the rationale behind choosing this area as a site for TIMS over flights. A portion of the region centered on the northern Bradshaw Mountains was selected because it contains plutons of all three alkalinity classifications (alkali-calcic, calc-alkalic, and calcic) present on DeWitt's map within a relatively small area (Figure 1). The site was flown in August of 1994 and the data received a few days before the writing of this manuscript. Most of this paper is devoted to the description of laboratory based spectroscopy and spectral simulations. These are required to gain insight into the correct procedures for enhancing the relatively small differences in the low spectral resolution TIMS data. Details of the TIMS analysis will be given at the presentation of this paper during the Workshop.

2. EXPERIMENTAL

High spectral resolution thermal emission data for the current work were acquired using a Mattson spectrometer at the Thermal Emission Spectrometer Laboratory of Arizona State University. A suite of minerals was selected that represents the major minerals described in the DeWitt paper. These include: the plagioclase feldspars albite through anorthite; the alkali feldspars microcline, orthoclase, and anorthoclase; the mafic minerals hornblende and biotite; and quartz. The purity of these mineral samples has been verified using microprobe analysis. All samples were particulate in form with a grain size of approximately 1mm. Emissivity spectra were calibrated using the technique of Ruff et al. (in preparation).

Mineral spectra were mixed synthetically using a computer. The linear mixing of spectral endmembers has been shown to be a valid technique by Thomson and Salisbury (1993). By mixing together in different proportions the spectra of the mineral suite, synthetic versions of granitoid rocks have been created. Because the mineralogy descriptions of the rocks in the DeWitt paper were presented without actual abundances (minerals were listed simply in order of decreasing abundance), all synthetic rock spectra are approximations. Textbook mineral modes (Ehlers and Blatt, 1982) were used to formulate the synthetic rock spectra.

To guide the choices necessary for TIMS data enhancement, TIMS channel bandwidths have been overlaid on all spectral plots. From the analysis of these plots, a strategy for image processing has been devised.

3. RESULTS

Figures 2 and 3 present individual mineral spectra. The feldspar spectra of Figure 2 are given in order of decreasing alkalinity from top to bottom and are displayed without normalization (i.e., depth of absorptions are accurate). As a group, the feldspars share many of the same spectral features as would be expected from crystal structure considerations. But upon closer inspection, a distinguishing trend can be noted. The shoulder present in the region of TIMS band 5 transitions to an absorption feature with decreasing alkalinity. This becomes especially apparent when compared with the emissivity of each mineral in the region of band 4.

In Figure 3, the remaining mineral spectra are plotted. These are also displayed without normalization but a scale change has been used to accommodate the deeper features. The depth of the biotite features is exaggerated because of the difficulty in obtaining a particulate sample with randomly oriented grains. In effect, the spectrometer is viewing only one side of the crystal, yielding a spectrum which is not representative of biotite in nature. For this reason, biotite has not been included in the synthetic mixtures.

The next plot depicts synthetically generated granitoid spectra. Figure 4 shows the spectral appearance of a generic granite, granodiorite, and tonalite which represent the three alkalinity classifications alkali-calcic, calc-alkalic, and calcic. Quartz and hornblende abundances are held constant in the mixtures at 25% and 10% respectively. The 65% total feldspar abundance is varied by composition to arrive at the three different rock types. The granite uses equal parts microcline and oligoclase. The more calcic granodiorite has andesine and labradorite in equal amounts. Finally, the tonalite contains the Ca-rich feldspars bytownite and anorthite.

As seen in the single mineral spectra, alkalinity discrimination is best observed in TIMS bands 4 and 5. The appearance of the band 5 feature as well as the decreased spectral contrast of the calcic plagioclases actually enhances the distinctive behavior of the rock spectra in bands 4 and 5.

4. DISCUSSION AND CONCLUSION

Based on the results of this work, it is theoretically possible for TIMS data to be used to discriminate between granitoid rocks of varying alkalinity. A ratio of bands 5 and 4 will yield values that can be used to enhance this discrimination. Using the technique of synthetically mixed rock spectra, many variations of mineral endmembers can be combined to determine whether the 5/4 ratio will persist as an alkalinity discriminator. With additional laboratory spectroscopy work and characterization of real samples, it may be found that the value of this ratio is unique and diagnostic of alkalinity.

The TIMS data from the Bradshaw Mountains site will be processed using the knowledge gained from this work. The map generated from the work of DeWitt will be compared to the processed TIMS images. At this time the effect of vegetation, rock coatings, weathering, and other real world variables has not been examined. Whether these factors completely confound the promising results seen in the lab is to be determined.

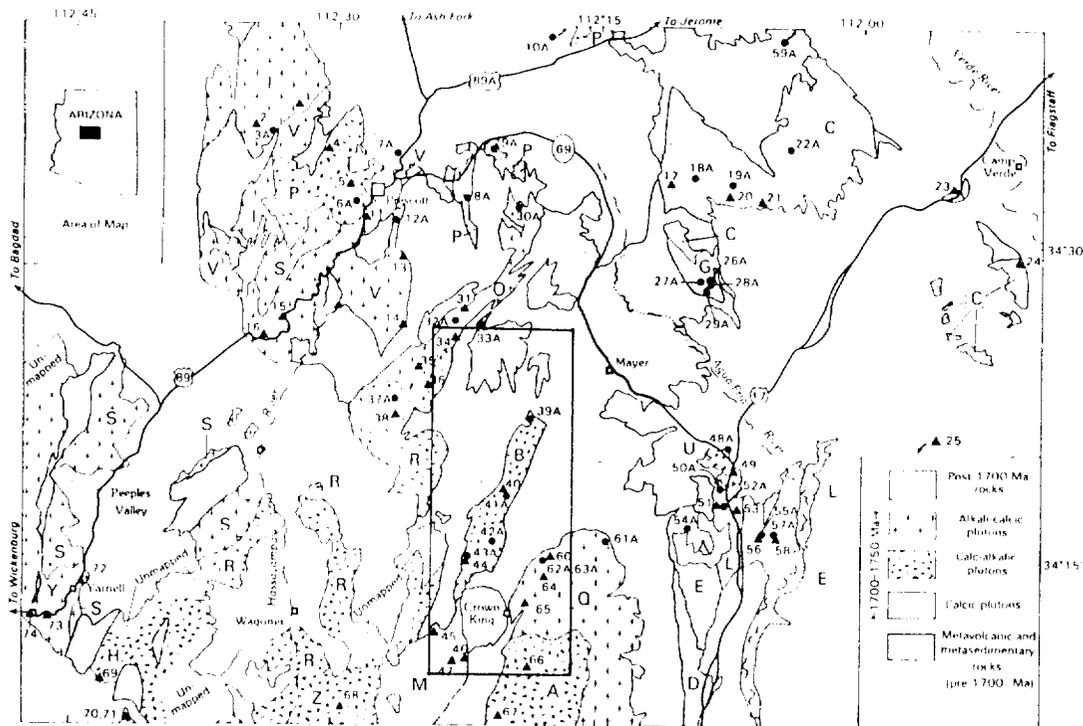
5. ACKNOWLEDGMENTS

I would like to thank the crew of the NASA C-130 for allowing me and the rest of the ASU group to fly along during the TIMS missions. We were treated like VIP's and encouraged to participate in planning. It was a rewarding and enjoyable experience.

6. REFERENCES

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Figure 1. Simplified geologic map of the Prescott area, north-central Arizona (from DeWitt, 1989).



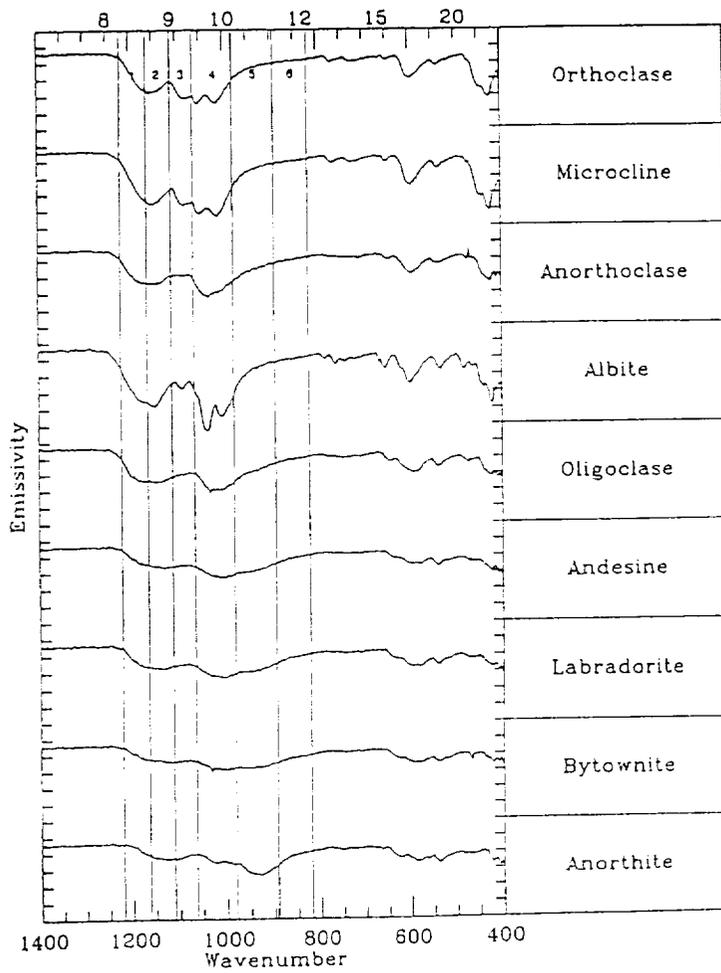


Figure 2. Spectra of feldspar suite.

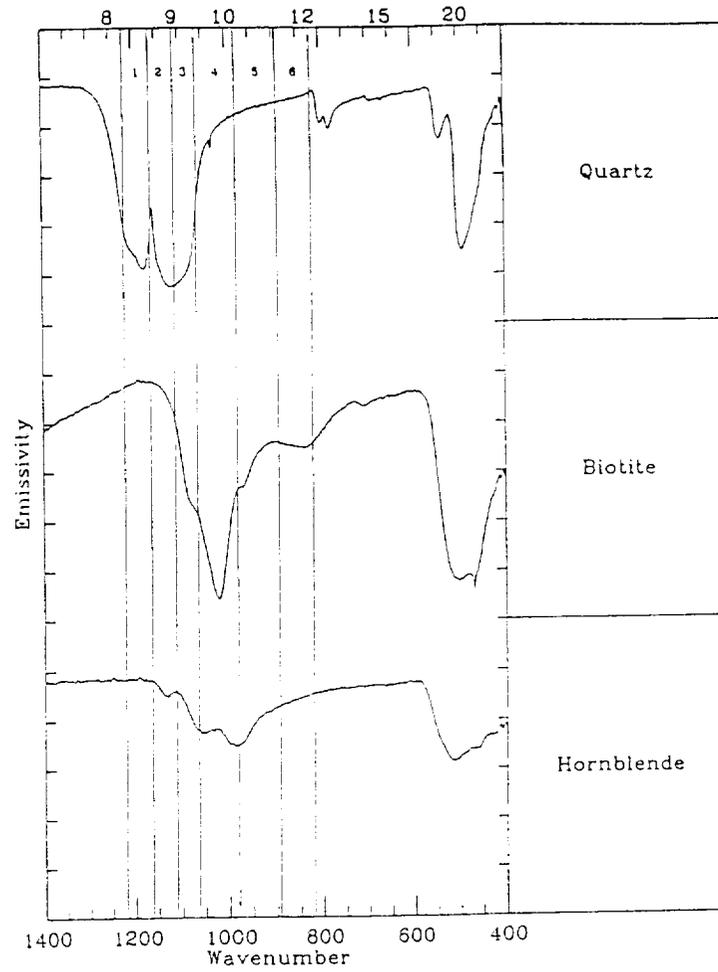


Figure 3. Additional granitoid suite mineral spectra.

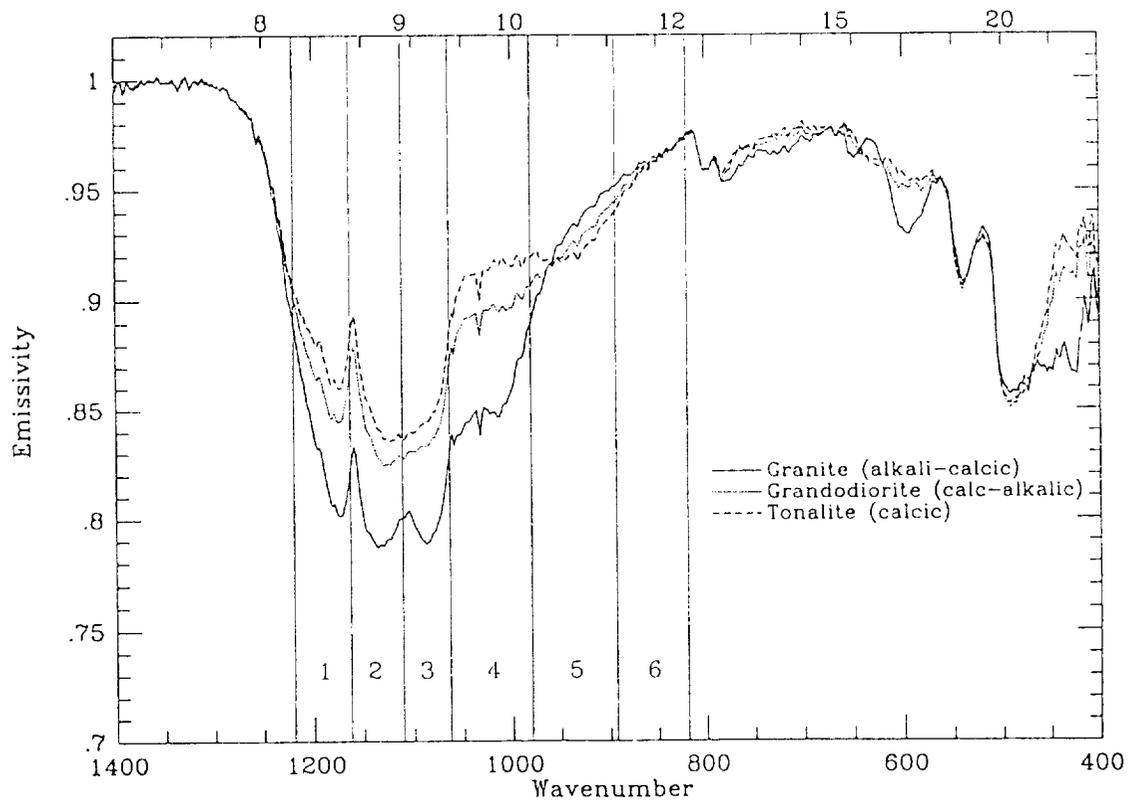


Figure 4. Synthetic rock spectra.