Near infrared spectra of white mica in the Belt Supergroup and implications for metamorphism

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ABSTRACT

The wavelength of the white mica (illite and muscovite) Al-OH absorption band near 2200 nm in 1036 samples from the Belt Supergroup and associated metasedimentary rocks was determined with a portable visible and near infrared reflectance spectrometer. The Al-OH wavelength decreases from 2225 nm in sub-biotite-zone samples to 2194 nm in sillimanite-zone samples; this decrease corresponds with an increase in total Al content of white mica from ~2.0 to ~2.8 atoms per 11 O atoms. These observations indicate that: (1) the frequency of the Al-OH vibration is controlled by the aluminoceladonite exchange reaction \[ \text{IV} \text{Si}^{+}{\text{VI}}(\text{Mg,Fe}^{2+}) = \text{IV} \text{Al}^{+}{\text{VI}}\text{Al} \], and (2) the reaction proceeds toward more Al-rich composition with increasing metamorphic grade. In these circumstances, Al-OH wavelength provides an indirect monitor of compositional variation and metamorphic grade.

Metamorphic grade in most of the study area is in the biotite zone or lower, yet Al-OH wavelengths in low-grade rocks define systematic patterns that correlate with depth of burial and later structural displacements. In higher grade areas, wavelengths generally decrease from the garnet isograd through the sillimanite zone; however, anomalies occur locally, and it is not clear whether these result from differences in bulk composition and mineral assemblage or whether they point to actual metamorphic or structural discontinuities.

These findings indicate that reflectance spectroscopy can yield valuable information on metamorphic intensity in rocks containing white mica, particularly in low-grade sequences where conventional indicators of metamorphic grade are lacking. Furthermore, this information can be obtained with field-portable spectrometers and the potential exists to obtain comparable results from airborne and spaceborne imaging spectrometers.

Keywords: Belt Supergroup, metamorphism, visible and near infrared spectroscopy, white mica, muscovite, illite, Idaho, Montana, low-grade metamorphism

INTRODUCTION

The Belt Supergroup of western Montana, northern Idaho, and eastern Washington and the stratigraphically equivalent Purcell Supergroup of Alberta and British Columbia comprise one of the thickest and most extensive Mesoproterozoic sedimentary sequences in the world (Fig. 1). Despite a large body of research that addresses the stratigraphy, sedimentology, economic geology, paleomagnetism, tectonics, and radiometric ages of the these rocks (e.g., Harrison 1972; Winston 1986; Link et al. 1993; Evans et al. 2000; Lydon 2000; Elston et al. 2002), there have been no comprehensive studies on the variation in metamorphic intensity across the region. Metamorphic grade in most areas is in the greenschist or subgreenschist facies (Ernst 1992), and petrologic methods applied to higher grade rocks are impractical because of fine grain size, lack of attainment of equilibrium, high-variance mineral assemblages, and absence of distinctive index minerals.

This paper demonstrates the use of visible and near infrared (Vis/NIR) reflectance spectroscopy to characterize variations in metamorphic intensity across the Belt Supergroup in western Montana and northern Idaho. Vis/NIR measurements are rapid and can be made with field-portable instruments or from airborne or spaceborne imaging spectrometers (Clark 2004). The focus here is on spectral characteristics of white mica (illite and muscovite), because it is present at all metamorphic grades and has

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FIGURE 1. General distribution of Belt and Purcell Supergroups (modified from Link et al. 1993).