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Differentiation of dolomite phases in outcrop using hyperspectral imaging

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Summary

Initial assessment of diagenetic phases and paragenesis in outcrops relies on a visual assessment of crosscutting relationships. Mimetic replacement and a lack of colour differences between mineral phases can result in incomplete sampling or misinterpretation of paragenesis. Hyperspectral imaging (HI) can detect individual mineral phases, based on composition and crystal size. This helps separate complex diagenetic processes that are typically referred to as one stage of paragenesis, such as the formation of zebra dolomites. In this study, we demonstrate the utility of HI to determine the number of carbonate phases and paragenetic sequence in a complex outcrop that has undergone several stages of diagenesis.

Method

An exposure of the Cathedral Formation in the main ranges of Alberta's Rocky Mountains was imaged using a hyperspectral camera capable of collecting shortwave infrared reflectance spectra between 1000-2500 um. Five images were collected along a 500 m transect at a distance of approximately 50 m. To guide the analysis of outcrop imagery (<5cm/pixel), several representative samples were taken along the outcrop and imaged at a higher spatial detail at the University of Alberta hyperspectral drill core imaging facility equipped with the same hyperspectral camera (<2mm per pixel). For the field and laboratory acquisitions, measurement of dark current and of a 99% reflectance white panel were used to calibrate imagery to reflectance. Spectra collected from the outcrop were initially classified into 16 groups using a statistical evaluation of the spectra. These groups were further evaluated, merged and labeled following the analysis of HI imagery of hand samples with petrographic analysis. Images of spectral groups reveal a limestone-dolomite transition only detected in the field through closely spaced HCl testing.

Results

Three major groups of replacement matrix dolomite, altered replacement matrix dolomite and dolomite cement were identified and differentiated in the outcrop (Figure 1). Four phases of saddle dolomite cements are also differentiated in the HI images, highlighting both pore-lining and filling phases. This study illustrates that several spectral classes can emerge from hyperspectral imagery in the presence of compositional and textural variability in carbonate phases. Altogether, the HI images collected from this exposure imply that there was an initial replacement of precursor limestone facies, followed by several phases of cementation that resulted in significant alteration of host rock margins. The results provide crucial information regarding the paragenesis and a map of diagenetic phases to be sampled for further analysis.

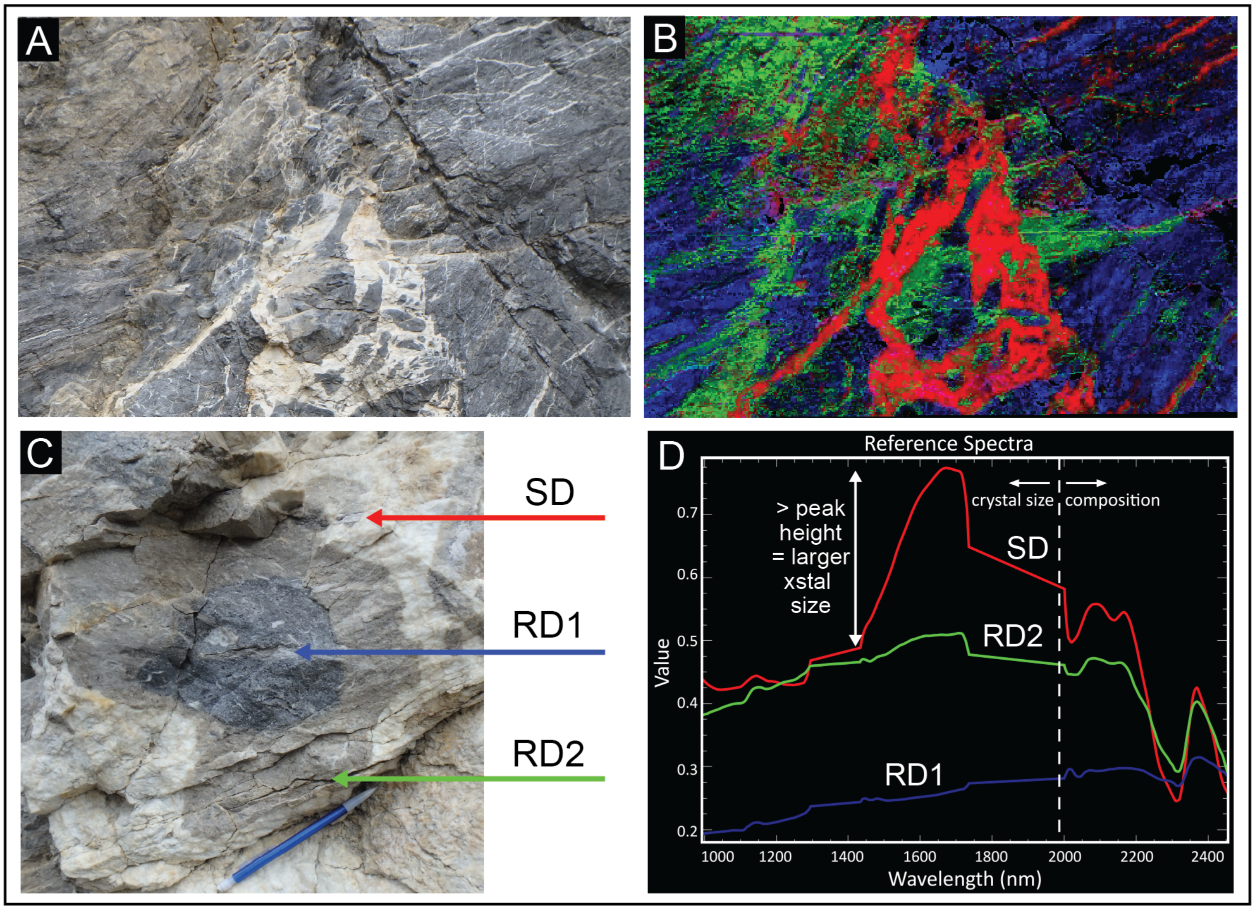

Figure 1: A) Exposure of the Cathedral Formation, Cambrian, along the David Thompson Highway. B) Hyperspectral imagery collected from the exposure. Blue is the first replacement dolomite phase (RD1), green represents the second replacement dolomite phase (RD2), and red represents the saddle dolomite cement phase (SD). C) Dolomite clast (RD1) with altered dolomite rim (RD2), surrounded by saddle dolomite cements (SD). D) Spectra associated with each dolomite phase in B.

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