[PS]Enhancing SEM Grayscale Images Through Pseudocolor Conversion*

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Abstract

The ability to visualize and interpret standard grayscale scanning electron microscope (SEM) images is limited by image contrast, magnification level, and the capability of the human eye to distinguish between subtle shades of gray. A pseudocolor conversion technique is described using freely available Image J digital image processing and analysis program that can improve the ability to interpret and communicate information contained within SEM images of shales. This technique is most suitable for backscattered electron images to enhance contrast variations to aid compositional interpretations, as illustrated by examples from the Eagle Ford, Haynesville and Eagle Ford shales.

Enhancing SEM Grayscale Images Through Pseudo-color Conversion

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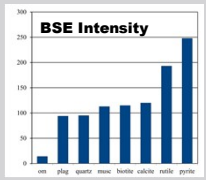
Introduction

- Digital SEM images are produced by assigning grayscale values to represent signal intensity measurements, such as from secondary electron (SE) and backscattered electron (BSE) detectors
- The ability to visualize and interpret standard SEM grayscale images is limited by: 1) image contrast, 2) magnification level, and 3) the capability of the human eye to distinguish subtle shades of gray
- The purpose of this poster is to illustrate the advantage of enhancing grayscale SEM images by pseudo-color conversion to improve the ability to interpret and communicate information contained in shale SEM images

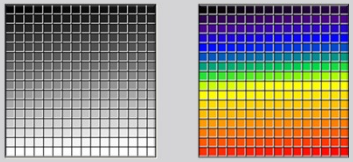


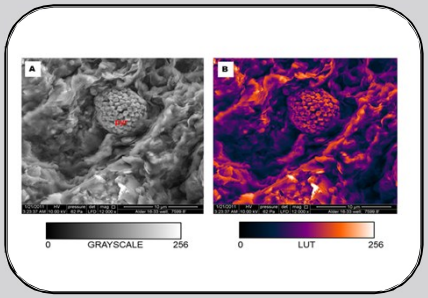
- Backscatter electron intensity is a function of the mean atomic number of the area sampled by the electron beam
- Chart (left) shows mean grayscale values (BSE intensity) for organic mater (om) and common minerals measured from an Ar-ion milled SEM image
- Minerals with similar BSE intensity are difficult to distinguish in standard SEM images because of similar grayscale values

Methods

- SEM images were acquired from drill core samples using a field emission SEM on uncoated, freshly broken and Ar-ion milled surfaces at low electron beam energy (10-15 keV) in a high pressure vacuum chamber (59-62 Pa)
- Pseudo-color images were created using public domain *Image J* digital image processing and analysis software by a process that substitutes grayscale values with color utilizing pre-defined color lookup tables (LUT's)

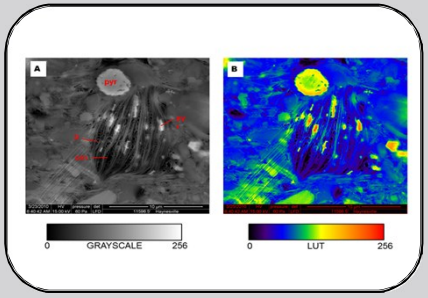
Pseudo-color Conversion





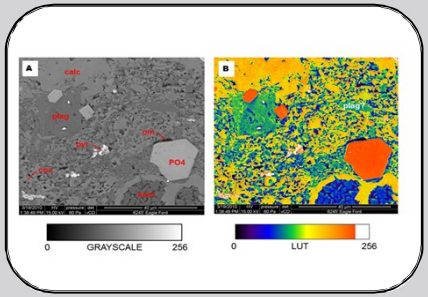
Broken Surface SE

Pseudo-color conversion may produce a more interesting SE image, but generally the grayscale images are adequate for interpreting surface morphology and texture from broken (rough) surfaces.



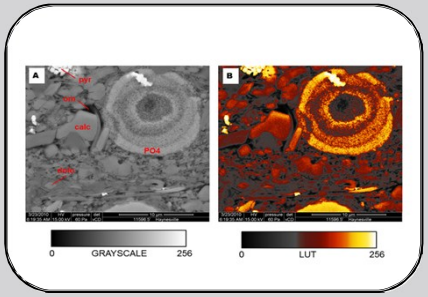
Ar-ion Milled SE

Pseudo-color conversion highlights surface artifacts (lower left), with only limited ability to reveal compositional contrast in SE images (e.g., organic matter & pyrite). Pores (p), appear black.



Ar-ion Milled BSE

Pseudo-color conversion is most effective in highlighting compositional variation in BSE images. Extremely smooth sample surfaces are required, such as produced by Ar-ion milling.



Ar-ion Milled BSE

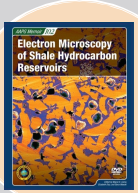
A wide variety of LUT's are available for pseudo-color conversions. This example highlights the distribution of higher atomic number (higher density) minerals such as dolomite, calcite and phosphate.

Conclusions

- Shale reservoir SEM images can be difficult to interpret due to subtle variations in the shades of gray displayed in standard grayscale images
- Pseudo-color conversions are rapidly and inexpensively accomplished using common digital image processing software, such as the public domain *ImageJ* program
- The primary application for pseudo-color conversion is to improve the ability to distinguish mineral composition and distribution from ion-milled backscattered electron (BSE) images
- Color enhancement is limited by: 1) the original quality of the grayscale image, 2) they type of LUT applied, and 3) mean atomic number contrast within the image area
- Mineral identification from BSE images requires independent calibration such as from energy dispersive x-ray spectrometry
- Caution is advised against aggressive use of image contrast and brightness adjustments as these techniques alter the original image fidelity which could lead to erroneous interpretations

Figures From

- Camp, W.K. and B. Wawak, in press, Enhancing SEM Grayscale Images through Pseudocolor Conversion: Examples from Eagle Ford, Haynesville and Marcellus Shales: AAPG Memoir 102.



New Publication:

Electron Microscopy of Shale Hydrocarbon Reservoirs

(AAPG Memoir 102)

***ImageJ* software available:**
http://rsb.info.nih.gov/ij