Sedimentary Rhythm Detection Based on Color Measurement
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Introduction:
To study past climate change, we can study sedimentary rocks. Because the process of sedimentation is highly dependent on climate, we can see climate changes reflected in the composition of this rock. For example, organic matter doesn't easily make it to the bottom unless the ocean is anoxic, so rock formed under anoxic conditions tend to contain more organic carbon.

For new rocks, we can sample the ocean floor to study this record directly. Many older samples, however, are destroyed when the plate they are on is destroyed through subduction zone activity. This lack of direct samples complicates the study of these older periods.

When one plate subducts beneath another, some of the subducting plate is scraped off and left behind on the upper plate. This residue is called an accretionary complex. Ocean floor samples are the preferred method of analysis because the rock in accretionary complexes tends to be tightly folded and deformed. However, with care, it is possible to reconstruct continuous sections and study these accretionary complexes.

This study was conducted with samples taken from an accretionary complex near Inuyama, Japan. A sequence covering a 6 million year timespan from the early Triassic was obtained from an outcrop in the Kiso River for analysis. Rocks were dated by comparing carbon isotope ratio variations to a known model for this time period.

Several species of rock are present in the sample. Black shale, dolomite, silaceous mudstone, argillaceous chert and pyrite (both nodules of about 1mm and thin lamination) were previously identified to be in the sample by visual examination (both of cut rocks and in the field) and by analysis of the composition of the rocks.

The aforementioned sedimentary rocks differ mostly in their biogenic component contents (such as SiO2 and total organic carbon content (TOC)) and terrestrial material such as AlO2. This can be used to identify the rocks. However, measuring this content directly is time-consuming and destroys samples.

As accretionary complex samples are already difficult to process, a new analytical process would serve to greatly enhance the study of prehistoric climate change by eliminating the need to destroy precious samples. Color measurement prevents the destruction of samples and decreases the amount of time spent on each sample, increasing total throughput.

Methods:
Color was measured approximately every centimeter for the length of the sample using a spectrophotometer. Points that were visibly heavily weathered were not measured.

Color measurements were made in the L*a*b* measurement system. “L*” is a measure of brightness, with high L* representing lighter colors and low L* representing darker colors. “a*” is a measurement of how red or green the rock is, with positive a* being red and negative a* being green. “b*” is a measurement of yellow and blueness of the rock- high b* is yellow while negative b* represents blueness.
After measurement, colors were correlated to rock type and to composition of the rock. Composition was determined by Mr. Sakuma in an earlier study.

Results and Discussion:

Note that low points in $L^*$ correspond to black shale, showing that the sedimentary rhythm can be correlated with color measurements.

The relationship between $a^*$ and $L^*$ is strongly negative for the entire section, indicating that dark rocks tend to be redder.

Regions of high weathering were associated with a high $b^*$. These regions typically had
“rusty” looking weathering, which was orange in color. The yellow component of the orange was detected by $b^*$. However, not every high peak in $b^*$ was associated with weather. At least two points were associated with pyrite instead, since pyrite's gold color is very yellow.

Also note once more the correspondence between low $L^*$ and black shale.

Figure 2: Peaks in $b^*$ correspond to weathering (or pyrite, not shown). Typical section shown.
The relationship between $a^*$ and $b^*$ is more complicated. For approximately the first 3.6 meters, the relationship between $a^*$ and $b^*$ is strongly positive. After that, the relationship is much weaker, though it appears to be slightly negative.
Figure 5: Note the relatively strong correlation for the first 3.6 meters (teal) and the weaker, negative correlation for the upper part of the section (blue).

It is possible that the correlation is due to mild weathering - the first 3.6 meters were more heavily weathered than the later parts of the sample, and the visible weathering tended to be orange in color. This would account for the positive correlation between red and yellow. Removing the visibly weathered points did not affect this trend, so any weathering causing this trend might not be visible to the human eye.

Figure 6: Iron and a*. Two points were removed because of visible pyrite in the region the iron data was obtained. Pyrite is an iron compound, so this skewed the measurements in those regions.
The most surprising finding from this study was the correlation between a* and the percentage of iron in the sample. It may be that iron in this section was primarily present in an oxidized state, causing a reddish color for areas rich in iron. The more iron, the more red the color, leading to the above trend.

Conclusions:
From the data, it is clear that a* and iron content are highly correlated in the absence of pyrite. Also, large peaks in b* tend to indicate either weathering or pyrite. These finding could be used to determine iron content of rocks in a more convenient way, without destroying samples. It might also be possible, in rocks with less pyrite, to use b* as a semiquantitative index of weathering, though more research would be needed for this. Also, it is possible to detect the sedimentary rhythm using color measurements.

References:
1. Sakuma H. High-resolution reconstruction of the deep-water environment and its relation with shallow-water environment during the End-Permian to the Early Triassic: Implication for the cause and consequence of ocean anoxia at the P/T boundary