

# REFLECTANCE SPECTROSCOPY OF REGOLITH PULPS AND CHIPS: IMPLICATIONS FOR THE DETECTION OF ALTERATION MINERALOGY IN THE LOWER SAPROLITE

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## BACKGROUND

Reflectance spectroscopy in the visible, near and shortwave infrared (350 - 2500nm) has been employed to study the spectral mineralogy of regolith materials. It has the advantage of being sensitive to both crystalline and amorphous materials, unlike some other diagnostic methods like X-ray diffraction (Clark 1999). However, the reflectance measured can be affected by sample preparation, particle size, sample concentration and optical geometry.

CRC LEME, in collaboration with Genalysis Laboratory Services, has investigated the effects of some of the routine laboratory treatments on spectral mineralogy, such as drying, crushing and pulping (particle size). In one specific study, regolith materials from a diamond drill intersection taken from the Jaguar Cu-Zn-Ag deposit, 4 km south of Teutonic Bore in the Eastern Goldfields Province of the Yilgarn Craton, were used. The main ore body is approximately 250 m below surface. The regolith materials, spanning a depth of 130 m, comprise colluvium-alluvium overlying saprolite, saprock and bedrock (basaltic composition).

All of the samples were dried at 121°C before crushing and pulverising due to the presence of moist clay in the regolith samples that cause problems during preparation. The regolith materials were crushed to approximately 2 mm, to simulate chips, using a Boyd crusher and rotary sample splitter. One half of each sample was left as chips while the other half was pulverised to <75 µm. Since all the samples in this study were dried, only two 'treatments' are considered in this exercise: dry pulps; and, dry chips. Other studies are in progress to test the effect of drying at 121°C, the temperature specified for quarantine treatment.

Both pulps and chips were put into chip trays separately, then scanned using the CRC LEME Hychips 6-1 prototype system. This system comprises a spectroradiometer mounted on a robotic table, which scans the spectral region of 350 nm to 2500 nm. Duplicate spectral scans, done simultaneously, were collected for each sample. Analysis of the spectra collected was done using the TSG Core software package.

In this paper, differences in spectral behaviour between dry regolith pulps and chips are given and the implications on the detection of alteration mineralogy in the lower saprolite discussed. The comparison of spectral variations between pulps and chips is effectively done using spectral parameters.

## SPECTRAL CHARACTERISTICS BETWEEN PULPS AND CHIPS

Four spectral variations between pulps and chips are discussed, namely the hull in the spectra, sample brightness or albedo, depth and shape of absorption peaks.

The hull is the background shape or curvature which is generally affected by Fe<sup>2+</sup> absorptions around 1000 nm and strong water and carbonate absorptions beyond 2500nm. In Figure 1, there is a fundamental difference in the hull between pulps and chips, suggesting that pulping may have released minerals that may not be otherwise detected in chips.

In general, the relative sample brightness or albedo of the pulps is higher than the chips (Figure 2). Scattering is dependent on reflection from the surfaces and internal imperfections. A large grain has a larger internal path where photons may be absorbed, whereas a smaller grain has more surface reflections compared to internal photon path length, or, the surface-to-volume ratio is higher. The difference in albedo is more pronounced in the darker regolith materials, such as the colluvium-alluvium and saprock/bedrock materials, than in the brighter saprolite. Also, the distinction between colluvium-alluvium and the saprolite in the pulps becomes more subdued than in the chips.

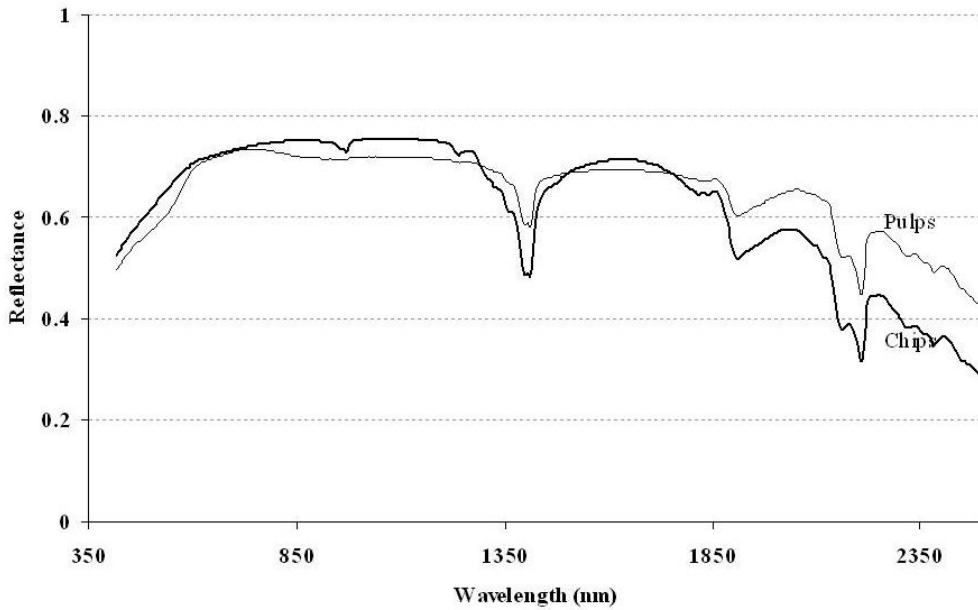


Figure 1. Reflectance hull of pulps and chips.

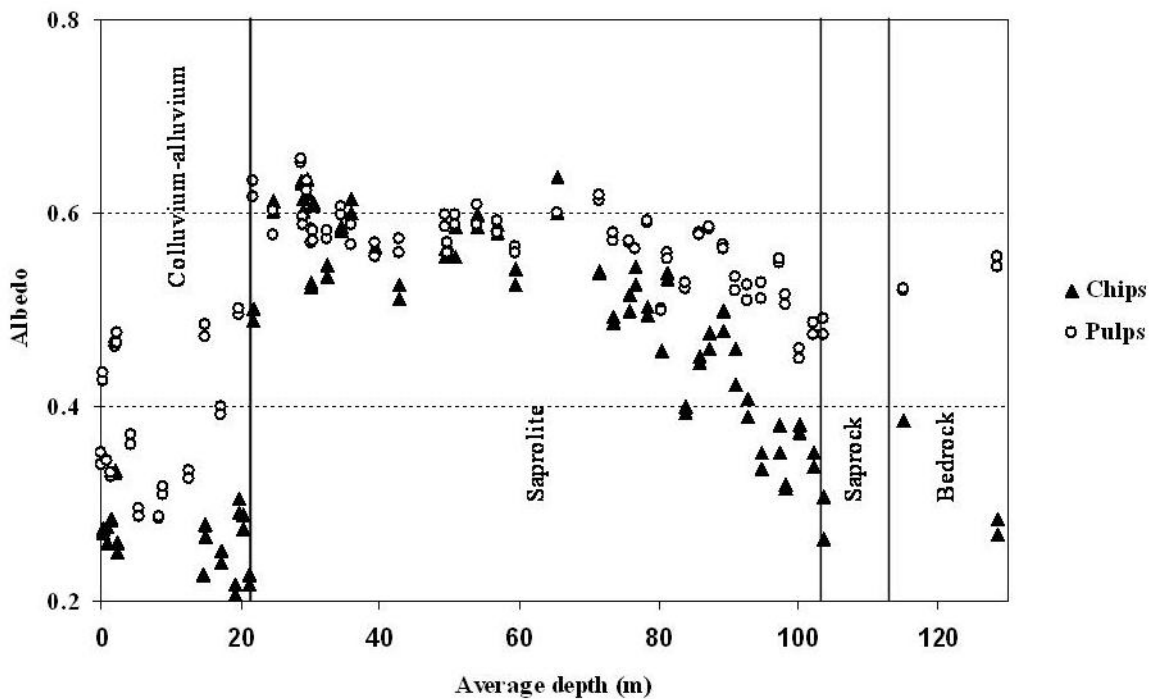
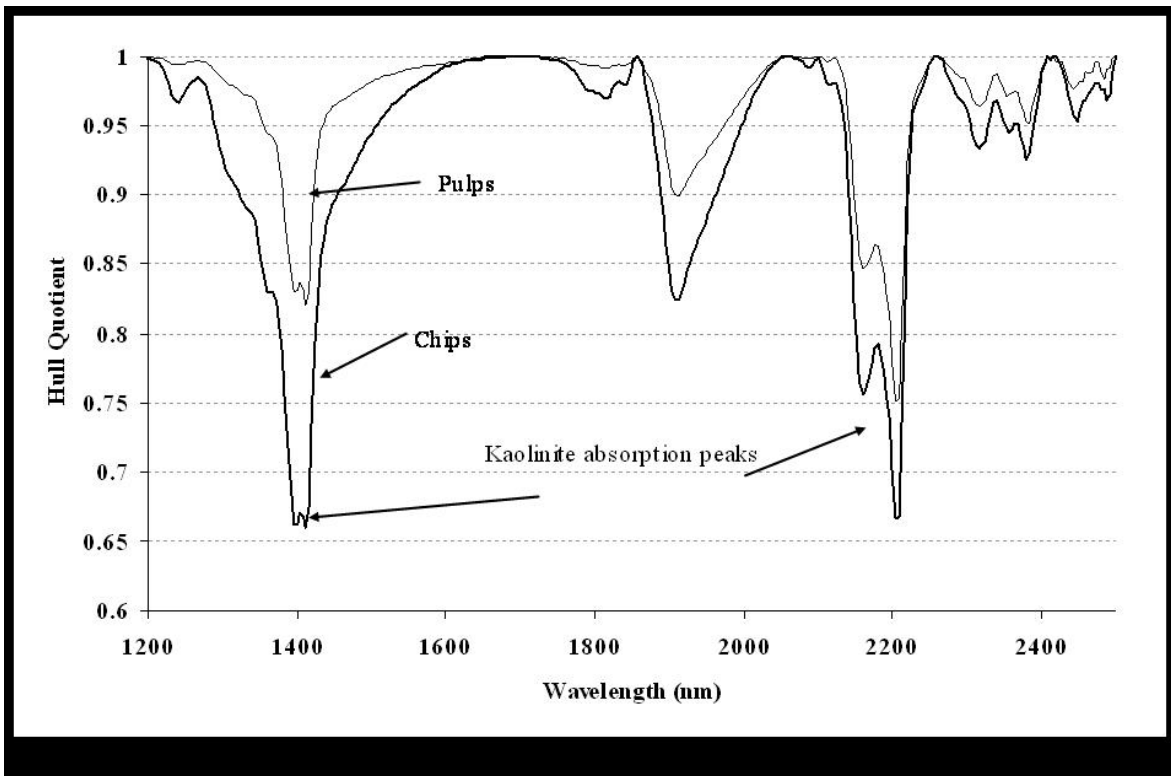


Figure 2. Albedo of pulps and chips versus average sample depth (m).

Absorption peaks are used to characterise minerals and each mineral has diagnostic absorption peaks at particular wavelengths. In general, depths of absorption peaks generally reflect the amount of mineral present and variations in the shape of the peak affects crystallinity.

Figure 3 illustrates a hull corrected stacked reflectance spectra of pulps and chips of the same regolith sample containing kaolinite. The hull correction is used to effectively accentuate the spectral signatures of kaolinite. In this example, the absorption peaks of kaolinite are much deeper in the chips relative to the pulps.



**Figure 3.** Hull corrected stacked reflectance spectra showing deeper absorption peaks for chips relative to pulps.

The shapes of the kaolinite absorption peaks are also subtly affected by particle size, as recognised by the kaolinite crystallinity index (KCI). The KCI is often used quite effectively in demarcating the boundary between transported and residual regolith. Chips show generally higher KCI values than pulps as in Figure 4. However, in terms of discriminating residual from transported, both pulps and chips are effective.

#### **ALTERATION MINERALOGY IN THE LOWER SAPROLITE**

*In situ* regolith materials consist mainly of the weathering products of the bedrock and there are persistent minerals still left which can reflect underlying lithology, as well as associated alteration mineralogy. In this investigation, the variation in the wavelength of the AIOH absorption feature associated with sericite or white mica is discussed. The AIOH absorption feature from a mixture of kaolinite and sericite, which is depicted here, is commonly seen as a single minimum, with wavelength intermediate between the two mineral phases. As the strength of the sericite component increases, so will the AIOH absorption feature move towards a higher wavelength.

A plot of variation in AIOH wavelength with sample depths is shown in Figure 5. The AIOH wavelength shows a reasonably sharp boundary between transported regolith materials and *in situ* weathered materials, indicating there are changes in the composition, particularly in the kaolinite, possibly due to Fe substitution. Interestingly, there are changes in the AIOH wavelength between chips and pulps. The variations are dominantly in the region of <0.5 nm difference, but can be much greater, as observed in the lower saprolite. It is most likely that the shift in AIOH wavelength is attributed to the change in the mixture of the AIOH related minerals, caused by concentration or dilution through pulping and homogenisation. As noted previously, the AIOH absorption feature in a mixture of different AIOH containing minerals tends to be seen as a single absorption feature, and may not be easily resolved as two absorption peaks. Overall, the trends for both pulps and chips in the AIOH variation over depths are similar.

The lower saprolite is of particular importance as it represents more closely the mineralogy related to underlying lithology and associated mineralisation as it is “less weathered”. It contains more of the sericite minerals. The AIOH wavelength moves towards the longer wavelength, indicating a transition from muscovitic sericite to phengitic sericite, the latter often distinctively associated with proximity of mineralisation.

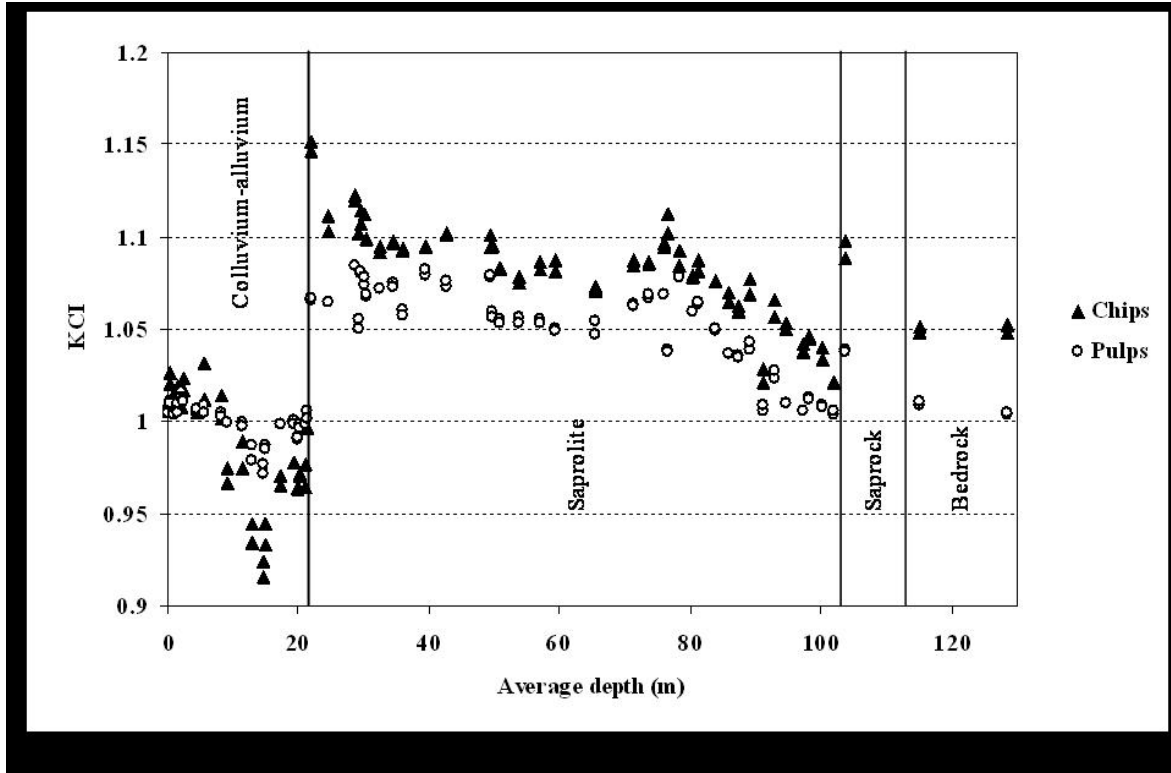


Figure 4. KCI index versus average sample depth (m).

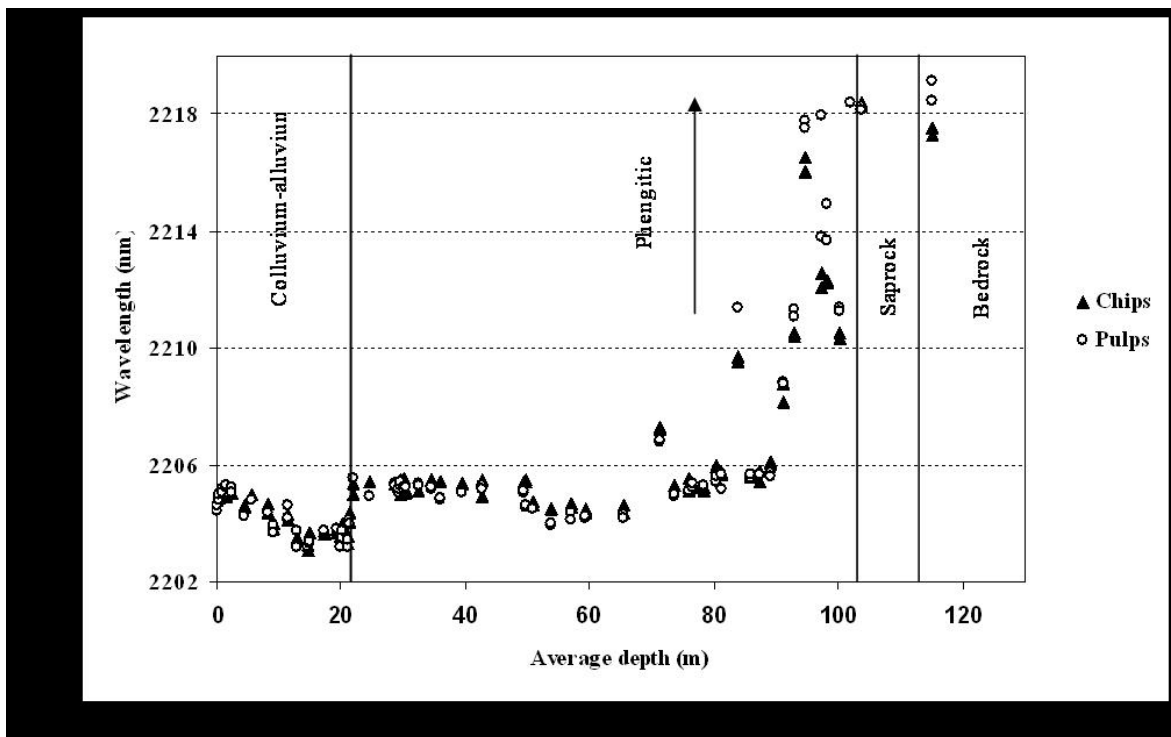


Figure 5. AIOH wavelength versus average sample depth (m).

## CONCLUSIONS

In the final analysis, there are differences in the spectral signatures between dry pulps and chips of regolith samples from the Jaguar site. The albedo in pulps is much higher than chips, indicating more surface reflections in the pulps. Mineral absorption peaks are deeper in the chips than pulps, suggesting that chips are much better sample media to work with than pulps, especially in terms of mineral identification. Pulping has somewhat affected crystallinity, shown by the KCI index, further indicating that the shapes of absorption peaks are affected. However, despite the differences in spectral behaviour between pulps and chips, both sample media are able to register the transported-residual boundary effectively as well as mapping out trends in the AIOH wavelength variations over depth. In spite of the weathering process, resistant minerals are still reflected in the saprolite, more strongly in the lower saprolite. The lower saprolite, with a dominant mineralogy of sericite, maps out compositional variation. The AIOH wavelength moves towards the longer wavelength, indicating a transition from muscovitic sericite to phengitic sericite, the latter composition often used as an empirical vector associated with proximity of mineralisation. Both chips and pulps are able to achieve this. Overall, consistency in the use of the sample medium becomes important, especially for comparison purposes.

## REFERENCES

- CLARK R.N. 1999. Spectroscopy of rocks and minerals, and principles of spectroscopy. *In*: RENCZ A.N. ed. *Remote Sensing for Earth Sciences - Manual of Remote Sensing*. Third edition. John Wiley and Sons, Inc., New York, 672 pp.