

# Determining impact of physical property for handling characteristics of bauxite ores

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## Abstract

Within the bauxite/alumina industry wet and sticky ore classification has been elusive to pin point outside of full scale plant operations. By investing in plant modification and processing methods, operations groups have mitigated some of the problems arising from these ores. An initial investigation using SEM, TEM, optical microscopy methods, XRD, XRF and other physical methods has compared bauxite samples from the Weipa region of Queensland. The samples being investigated were classified as either wet and sticky or non-wet and sticky by operations groups. This investigation is a compare and contrast between these coarse classifications using a diverse range of techniques. Very few differences between the ores have been found, suggesting the problem is caused by quite subtle difference between the ores.

## Key Words

Bauxite, problematic handling ore.

## Introduction

As economic drivers dictate the exploitation of previously overlooked or the extension of existing ore bodies, the possibility of encountering problems in the handleability of ores increases. Often these ores are below the water table and are colloquially termed “wet and sticky” due to the prevalence for adhesive material building up on processing plant. This obviously reduces through put, increases wear and reduces service life of the plant, thus adding the cost of processing. Fortescue Metals Group recently reported problems with “wet and sticky” ores and high alumina content as being partially responsible for up to \$400M in cost overruns at its Cloudbreak iron ore mine in Western Australia (West Australian, Thursday 30/4/09).

Significant intellectual investment has been made in learning how to mitigate such handling difficulties through processing plants. However as knowledge has advanced it may now be possible to develop greater understanding of the physics/mineralogy/chemistry behind why one ore may exhibit “wet and sticky” traits and why another does not. With such knowledge greater empowerment is offered to process managers in the control of such issues not withstanding the ability to make advanced decisions on the suitability of ore bodies for mining or even how much investment in processing plant is required.

A number of characteristics may play a part in the “wet and sticky” phenomena such as particle shape, size, mineralogy and chemistry of the major minerals in the bauxite. However mineralogical composition and the properties of those minerals can vary significantly within small areas of deposits (Sadler and Gilkes 1976). This is particularly true for the ultra-fine clay minerals for example kaolin clays (kaolinite, halloysite) and iron oxides whose small size suggest they will make a large contribution to key properties such as, surface area and surface charge.

## Methods

### *Samples*

Four samples from the Weipa region of Queensland, the samples were classified as WS (wet and sticky) or NWS (non-wet and sticky) by the operations group. As received samples were cone-and-quartered to take representative samples this was achieved with out any pre-treatment such as sieving.

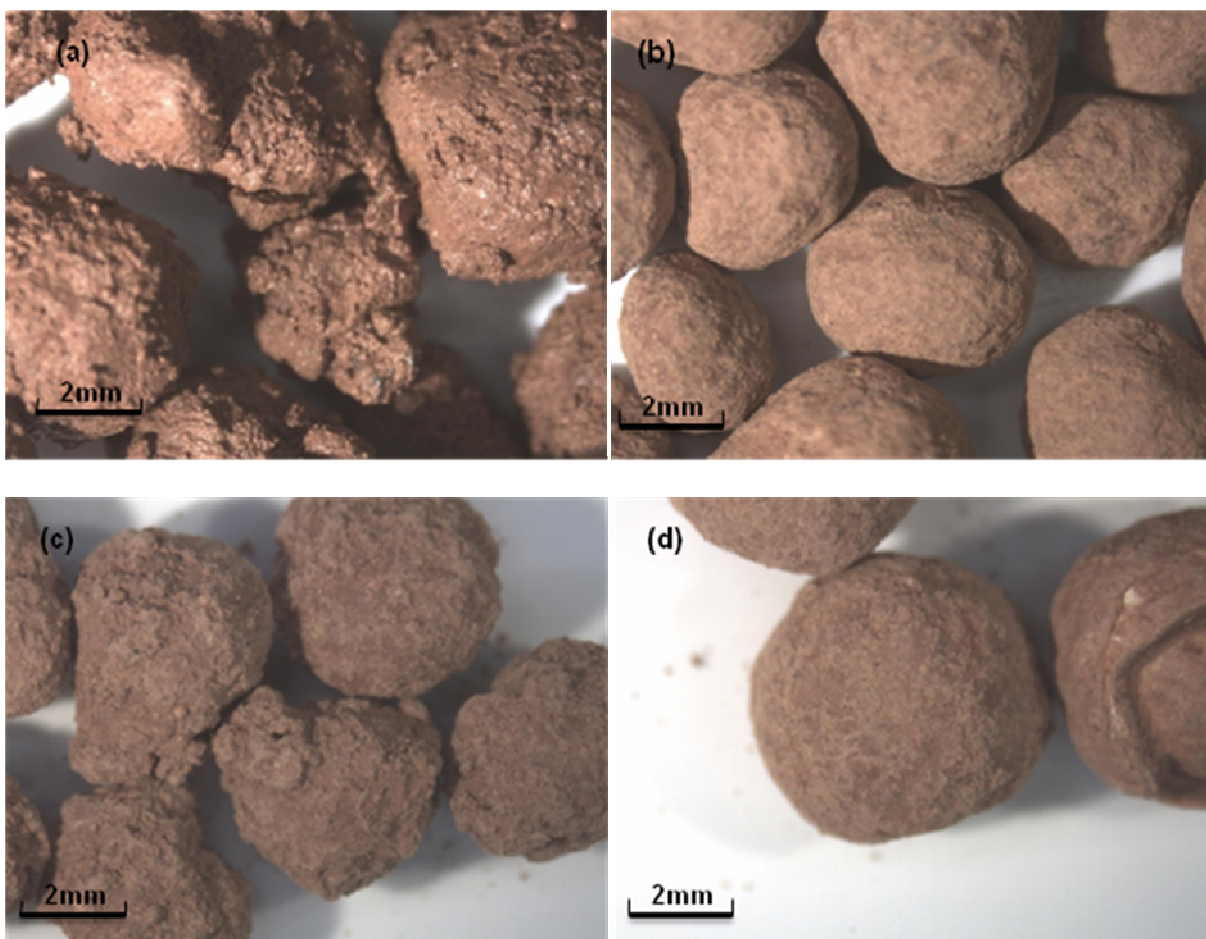
### *Techniques*

The appearance of the as received samples was recorded using optical microscopy. Optical microscopy was conducted using an Olympus Stereo Microscope SZ60 magnification range: ×10 -×63 with Lumenera

Infinity Lite camera. The colour of the sample were determined by comparison with the Munsell® Soil Colour Charts (Munsell Colour Co. 2000) for the samples in the, as received, dried and powdered (ring-milled) states; comparisons were made on a white ceramic tile under daylight. Particle size distribution was determined using Endecotts calibrated sieves and sieve shaker. The bulk chemistry of the samples was determined by XRF of fusion beads developed using 12:22 flux with 1:10 sample to flux ratios using a Philips PW1404 Spectrometer. X-ray Diffraction of randomly oriented powder specimens was carried out using a Bruker D8 Advanced instrument using a LynXeye detector for a 2θ range of 5 to 80 degrees with a 0.02 degrees step size. Radiation was copper K<sub>α</sub> with an accelerating voltage of 40kV and current of 40mA. Samples were prepared using a ring mill for 2.5 minutes. Patterns were analysed using EVA software. Scanning electron microscopy was carried out using Zeiss Evo 40XVP. Samples were prepared by platinum/palladium coating (thickness: 2nm). Stokes' law was used to separate the Clay (<2 μm) fraction from the remainder of the sample (Brindley and Brown 1980). The morphology of the minerals in the clay fraction was investigated by JEOL 2011 transmission electron microscope (TEM) operating at 200kV with an Oxford Instruments EDS.

## Results

The Bauxites investigated are relatively uniform size ball shape materials (Figure 1) described as pisoliths after Taylor *et al.* (2008). The WS samples (Figure 1a) were wet and the surface of the pisoliths was coated with muddy materials, the texture of this “muddy material” is clearer in Figure 1c. The alternative NWS sample, both as received (Figure 1b) and dried (Figure 1d) show the surface of the pisoliths appears to be smooth. Table 1 summarises the colour of the bauxites which are red to light red in Munsell® Soil Colour classification (Munsell Colour Co. 2000).



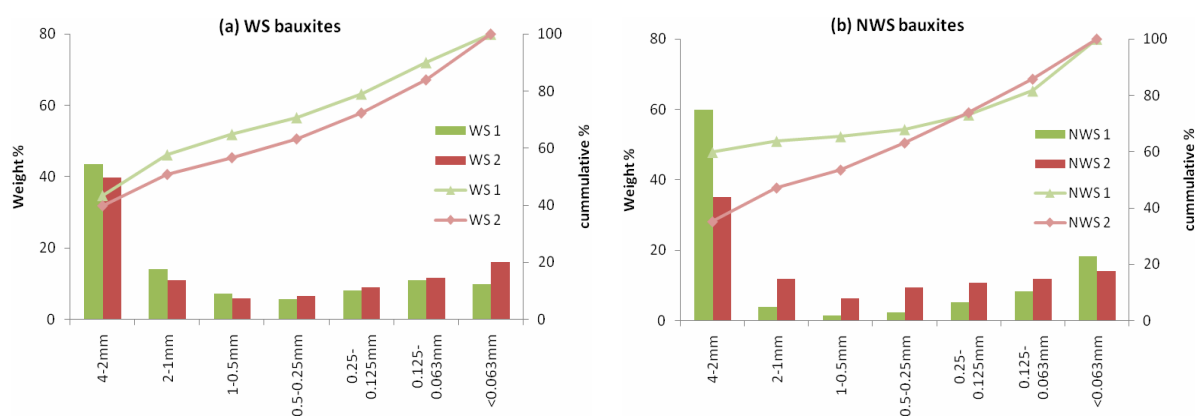
**Figure 1. Appearance of bauxites; WS as received (a), NWS as received (b), WS dried (c) and NWS dried (d). Comparing to NWS bauxites, the surface of the WS bauxites is rough and covered with fine and large particles. The coating on the surface is clearer when bauxites is dried.**

**Table 1. The colour of WS (wet and sticky) and NWS (non wet and sticky) bauxites for “as received”, “dried and “ring milled” sample.**

Sample Name	as received		dried		ring milled	
	Munsell	colour	Munsell	colour	Munsell	colour
WS 1	10R4.5/6	red	2.5R5.5/6	red - light red	2.5YR5/6	red
WS 2	2.5YR4/6	red	2.5YR6/6	light red	2.5YR5/6	red
NWS 1	2.5YR5/8	red	2.5YR5/6	red	2.5YR5/8	red
NWS 2	2.5YR4/6	red	2.5YR6/6	light red	2.5YR5/6	red

XRD indicated that both types of bauxites contain gibbsite, boehmite, kaolin, hematite, and anatase. Quartz was detected in one of the NWS bauxites when analysing the whole sample. Additional goethite peaks became detectable for the <63µm sample for both type of bauxites. In addition the <63µm sample also has higher boehmite/gibbsite ratio across the sample set. Thus the mineralogy of WS and NWS bauxites are very similar.

The WS bauxites were found to have a pH of 6.3 while NWS, had pH 6.0 (solid: deionised water=1:5). Macroscopic particle size distributions of dried samples are presented in Figure 2.



**Figure 2. Macroscopic particle size distribution of dried WS (a) and NWS (b) bauxites. More than 40wt% of WS is larger than 2mm (granule size) particles. One of NWS is similar to WS, but 60wt% of NWS 1 is larger than 2mm and it contains very little coarse sand size (1-0.5mm) particles.**

Table 2 shows the chemical compositions of bauxites as developed using WD-XRF. WS bauxites have slightly higher LOI at 1000°C, higher Al<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub> while NWS bauxites have more SiO<sub>2</sub> and Fe<sub>2</sub>O<sub>3</sub>.

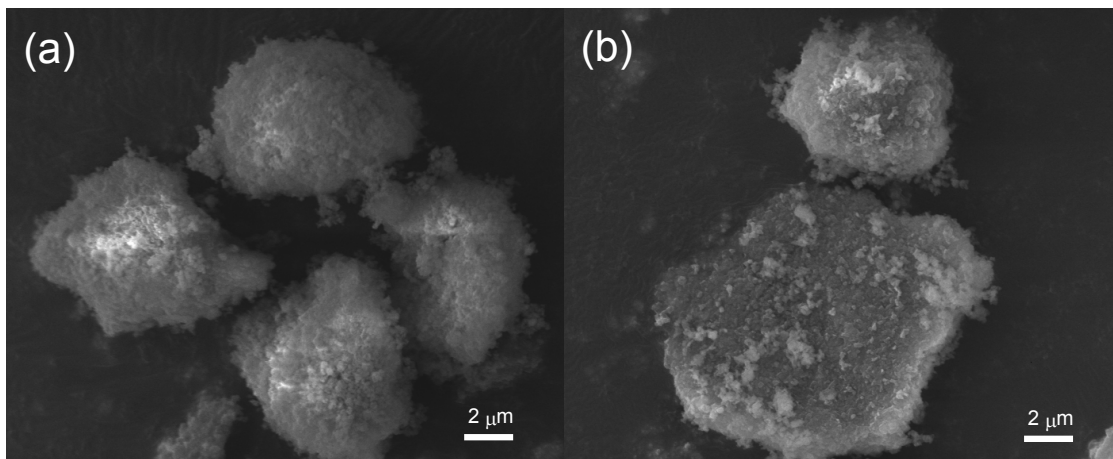
**Table 2. Chemical composition of WS and NWS bauxites (mean values).**

Sample	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	K <sub>2</sub> O	Na <sub>2</sub> O	MgO	CaO	BaO
UNITS	%	%	%	%	%	%	%	%	%
WS mean	56.6	4.12	12.5	3.22	0.003	0.02	0.02	0.01	0.002
NWS mean	55.2	5.73	13.8	2.90	0.007	0.02	0.03	-0.01	0.002

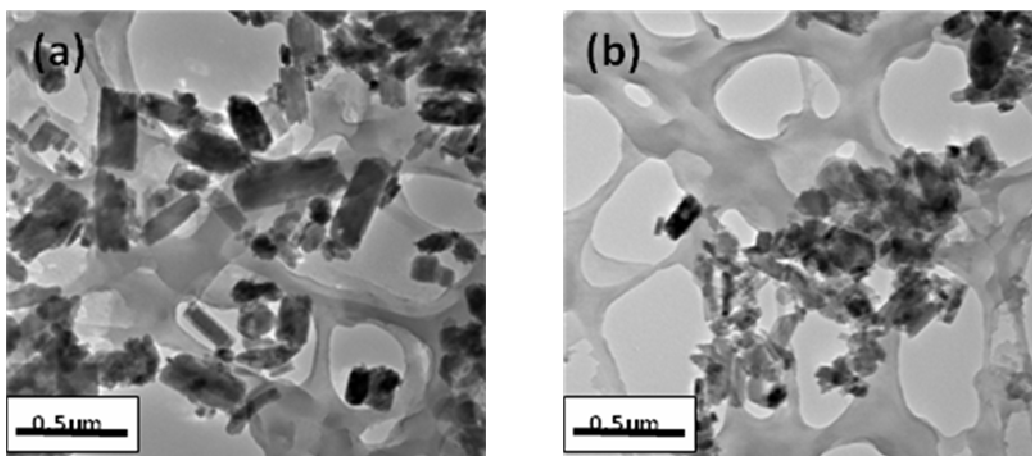
Sample	V <sub>2</sub> O <sub>5</sub>	Cr <sub>2</sub> O <sub>3</sub>	MnO	ZrO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	SO <sub>3</sub>	LOI <sub>1000</sub>	Sum
UNITS	%	%	%	%	%	%	%	%
WS mean	0.034	0.023	0.03	0.121	0.058	0.05	23.3	100.0
NWS mean	0.038	0.030	0.02	0.118	0.062	0.05	21.9	100.0

Figure 3 (a) and (b) show SEM secondary electron micrographs for both the WS and NWS respectively. These micrographs are of the <63µm cut of samples after dry-sieving. WS samples tended to be covered by fine components adding complexity to EM examination, whilst NWS often show well crystallised surface which may be gibbsite.



**Figure 3. SEM secondary electron images of WS (a) and NWS (b) bauxites. The surfaces are covered with fibrous and fine particles.**

TEM observation of the clay size fraction shows that the WS and NWS are similar, however, individual rectangular shaped crystals can be observed more clearly in WS (Figure 4 a) than in NWS samples (Figure 4 b).



**Figure 4. TEM images of WS (a) and NWS (b) bauxites of the clay size (<2μm) fraction.**

### Conclusion

At this stage, few differences in properties other than handleability between the WS and NWS bauxites were determined. This suggests that the properties are determined by quite subtle difference between the ores and that more detailed investigation and/or additional properties which might be related to handling problems is required.

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