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TRIBOLOGICAL BEHAVIOR OF JASPILITE EVALUATED BY MICRO-SCRATCH TEST

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Abstract. *The aim of this study is to characterize the tribological behavior of a banded iron formation known as jaspilite, which has two main minerals, hematite and jasper. Linear scratch tests were performed with two types of diamond indenters, Vickers and Rockwell, and different normal loads. Critical loads for mechanisms transitions (burnishing, ploughing, in-track and out-of-track cracking) were determined for each indenter and mineral. Critical transition loads are considerably lower for Vickers indenter, which resulted in a non-observation of moderate wear mechanisms (burnishing and ploughing). The ploughing mechanism was not observed in jasper. The quartz vein in the samples influenced the scratch response of both minerals, tending to embrittle them. Two types of iron oxide with different transitions loads were identified. Afterwards, Vickers scratch tests were done with five different normal loads (0.2, 0.5, 2, 5, e 10 N), as a result, the track width increased with applied normal load.*

Keywords: *Linear scratch test, jaspilite, wear mechanisms, abrasive wear.*

1. INTRODUCTION

Mineral exploration is very important to Brazilian economy. In 2015, its profit exceeded R$78 billion. The first step of extraction is geological prospection, which is usually done by percussion drilling using a tool known as diamond crown bit (Tottola, 2007).

Tottola (2007), Menegáz (2008) and Gava *et al.* (2013) were successful in the tribological characterization of the crown bit metal matrix, which resulted in an increase in their field performance.

Beste *et al.* (2004) affirmed that it is possible to understand the wear of the drill by linear scratch test on the counter surface, the rock. Several types of rock were tested, its wear mechanisms and transition loads were determined. Desa and Bahadur (1999) used the scratch linear test as a method to characterize ceramics since it is much easier to analyze the wear mechanisms in a single abrasive event. Zhang *et al.* (1988) studied the effect of the type of indenter on the wear of a ceramic material.

In this work, a first tribological approach of jaspilite from Serra de Carajás, in the state of Pará- Brazil is done. Jaspilite is a banded compact siliceous rock consisting of interbanded jasper (red chert) and hematite. This rock was chosen because of the diamond crown bits' low performance when in contact with this lithotype, moreover there are few tribological studies about this stone.

2. EXPERIMENTAL PROCEDURE

Samples, measuring 60 mm X 50 mm X 20 mm, were ground and polished to 1 μm diamond grit then cleaned with acetone in an ultrasonic device. Figure 1 shows the sample after polishing and it could be seen the banded structure characteristic of jaspilite.

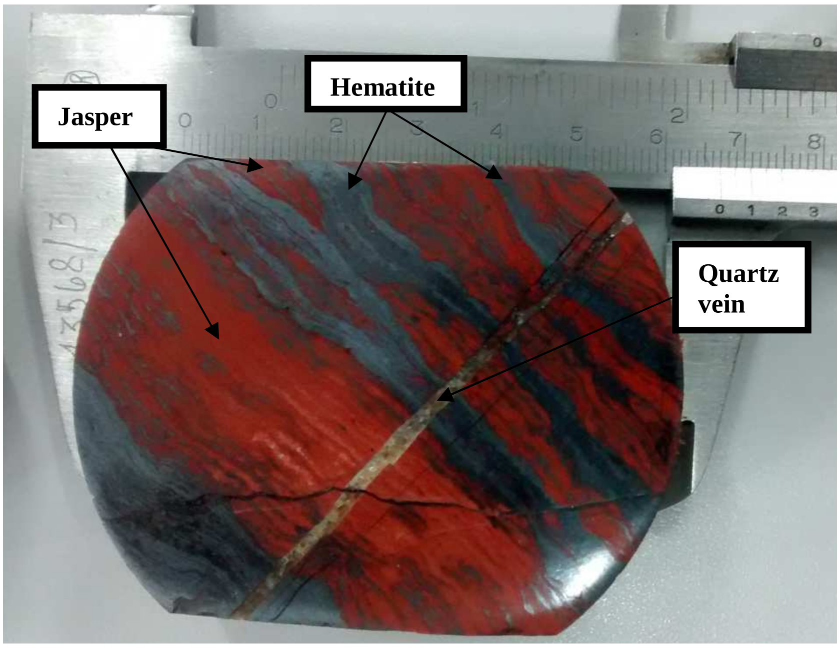

Figure 1. Sample after polishing.

Linear single-pass scratches were done in a CETR/Bruker Universal Micro Tester. The tests were run under dry condition at room temperature and 0.05 mm/s constant speed. The scratches had a minimum length of 5 mm and the distance between them is 10 times the scratch width.

Scratches were done with Rockwell and Vickers (edge parallel to scratch) indenters with constants loads ranging from 2 to 90 N and 0.2 to 10 N respectively. Moreover, tests with progressive loads were performed for Vickers indenter in order to obtain greater accuracy of the transition loads. The wear tracks were analyzed by stereomicroscopy and optical microscopy and the transition loads were determined.

For the evaluation of the normal load effect in the scratch width, five scratches were done with the Vickers indenter in each load (0.2, 0.5, 2, 5 and 10 N). Twenty-five widths were measured in each mineral for each load using an optical microscope.

3. RESULTS AND DISCUSSION

The critical loads for mechanisms transitions on Vickers tests were much lower than in the Rockwell tests and both burnishing and ploughing mechanisms were not observed, as presented in Tab. 1 and illustrated in the following figures. Compared to Rockwell, the Vickers is a sharp indenter, which can generate an elastic-plastic indentation stress field, and consequently, to a more severe form of fracture leading directly to wear (Lawn and Wilshaw, 1975; Hutchings, 1992). The in-track cracking mechanism precedes out-of-track cracking in all tests and minerals.

Table 1. Wear mechanisms and its loads intervals for Vickers and Rockwell indenters.

			Mechanism			
Indenter	Mineral	Phase	Burnishing	Ploughing	In-track cracking	Out-of-track cracking
Vickers	Hematite	Light	-	-	0.2 – 0.4 N	> 0.3 N
		Dark	-	-	-	> 0.2 N
	Jasper	-	-	-	0.2 – 0.5 N	> 0.4 N
Rockwell	Hematite	Light	2 - 10 N	8 - 49 N	41 - 54 N	> 50 N
		Dark	-	2 - 20 N	14 - 26 N	> 23 N
	Jasper	-	2 - 10 N	-	8 - 58 N	> 54 N

Besides hematite and jasper, the samples are also constituted of quartz veins. This mineral influenced the behavior of both hematite and jasper near to it, tending to embrittle them as can been seem by the wear mechanism changing on hematite on Fig 2 (left side). The quartz vein itself exhibited a more brittle behavior than the minerals studied, as can be seen in Fig. 2 (right side).

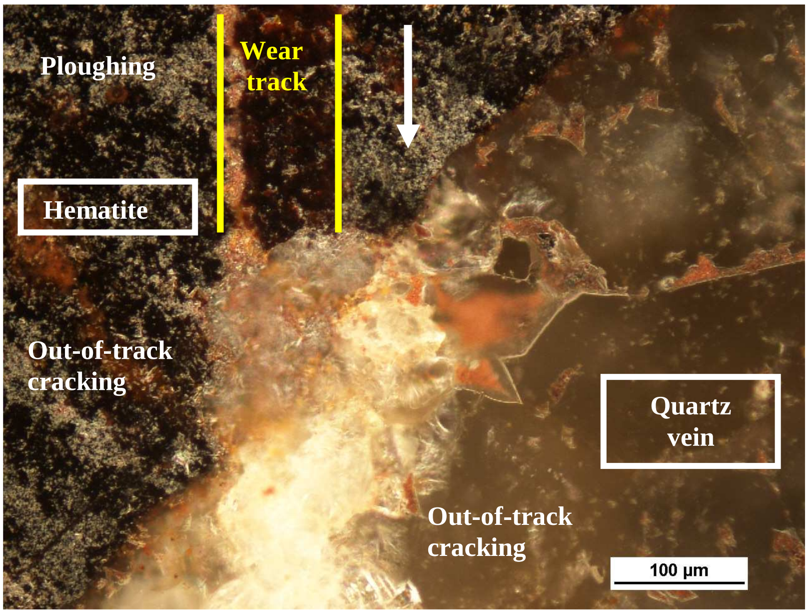

Figure 2. Optical micrograph – Quartz vein brittle behavior and its influence. Transition from ploughing to out-of-track cracking on hematite and out-of-track cracking on quartz vein (28 N - Rockwell). Note: The white arrow indicates the direction of the scratch.

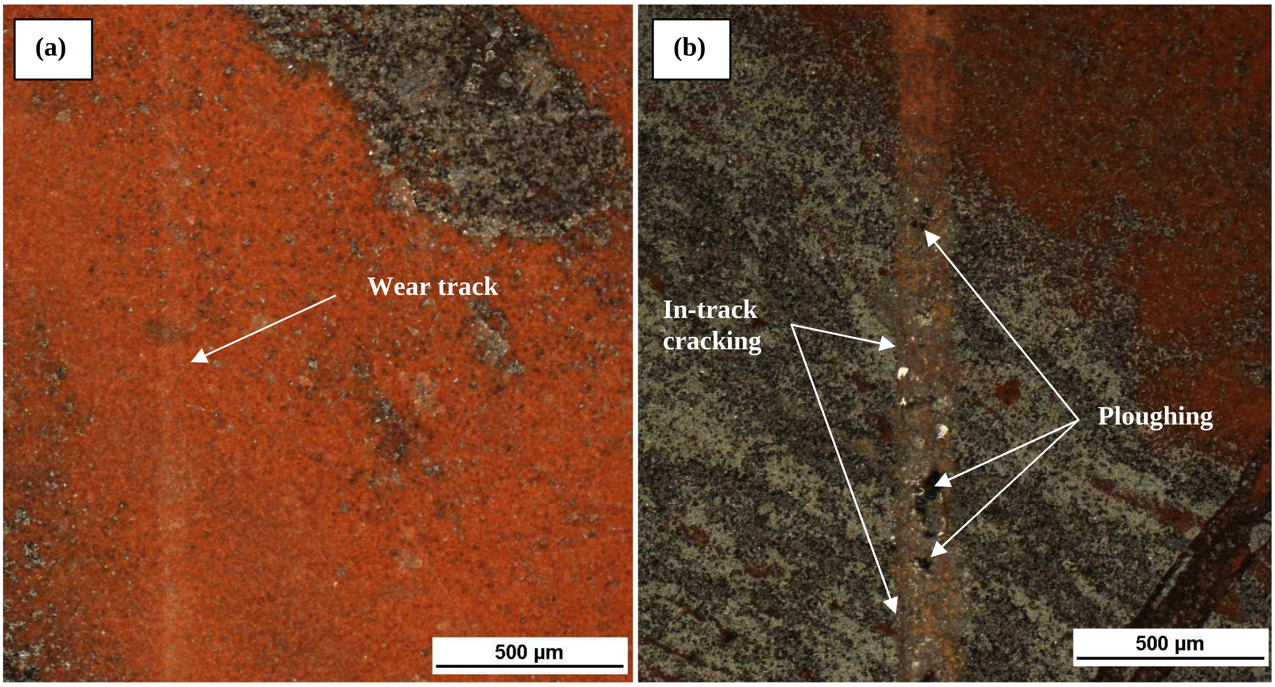

Figure 3. Optical microscopy - (a) Burnishing on Jasper - 3 N (Rockwell) (b) Transition between ploughing and in-track cracking on hematite and in-track-cracking on jasper - 49 N (Rockwell)

As can be seen in Fig. 3a, little or no damage was observed in some mineral phases, when the burnishing mechanism is dominant, which were the case only for the Rockwell indenter. Jasper and hematite's dark phase presented this kind of response.

Fig.3b presents the transition between ploughing and in-track cracking mechanisms. The ploughing mechanism is more visible than the burnishing, but still no distinguishable cracks occur. The latter mechanism is characterized by removal of material by cracking only between the borders of the wear track, as we can be seen in Fig. 3b.

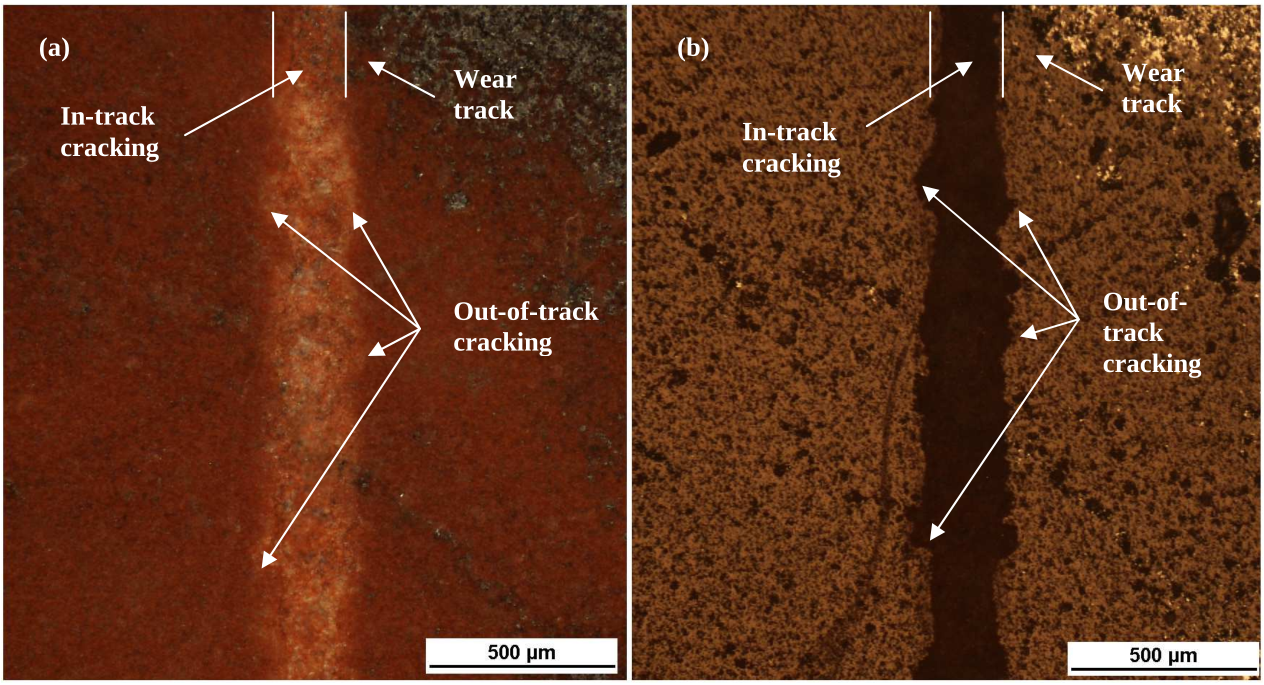

Figure 4. Optical microscopy. Out-of-track cracking on Jasper - 58N-Rockwell- (a) Dark field (b) Bright field

According Beste *et al.* (2004), when the load is high enough the cracking mechanism could be expanded far away from the wear track, configuring the out-of-track cracking. This mechanism is easily spotted due the borders of the track been very irregular (Figures 4 and 5). Both in-track and out-of-track cracking were observed in almost all tests conditions except for the dark phase in hematite when tested with Vickers indenter.

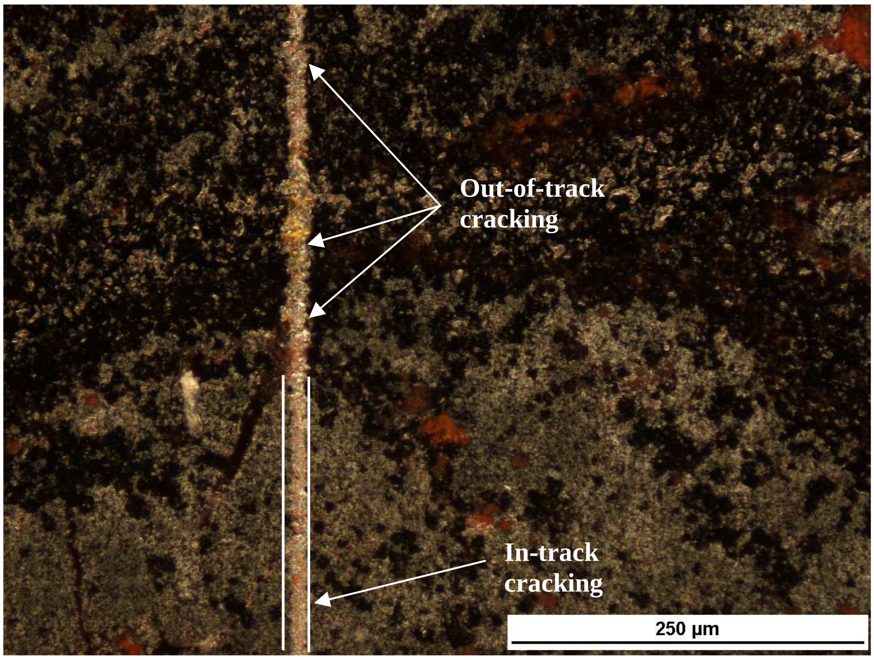

Figure 5. Optical microscopy - In-track cracking on light hematite phase and out-of-track cracking on dark - 0.2 N-Vickers

It was observed the existence of two different features, one dark and one lighter, on hematite veins (Fig. 5 and 6). These oxides presented different responses to the scratch, the dark one presented lower transition loads than the light, which could indicate a more brittle behavior leading to more severe wear mechanisms.

Apparently, no ploughing was observed on jasper, in both, Vickers and Rockwell tests, which means, according to Beste *et al.* (2004), that jasper has a less ductile character.

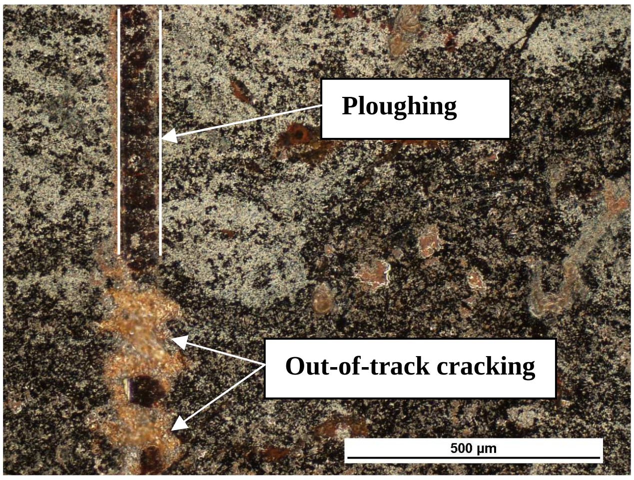

Figure 6. Optical microscopy - Hematite -28 N – Rockwell - Ploughing on light phase and Out-of-track cracking on dark phase

In the tests varying the load with the Vickers indenter, the scratch width increased with normal load, as expected (Fig. 7). The nonlinearity of the curve can be explained by the mechanism changes with the applied loads, see Tab 1. Except for the load of 0.2 N, hematite's dark and light phases presented the same wear mechanism and consequently have, practically, the same scratch width. Therefore, no distinction was made between phases to obtain the scratch width in the hematite.

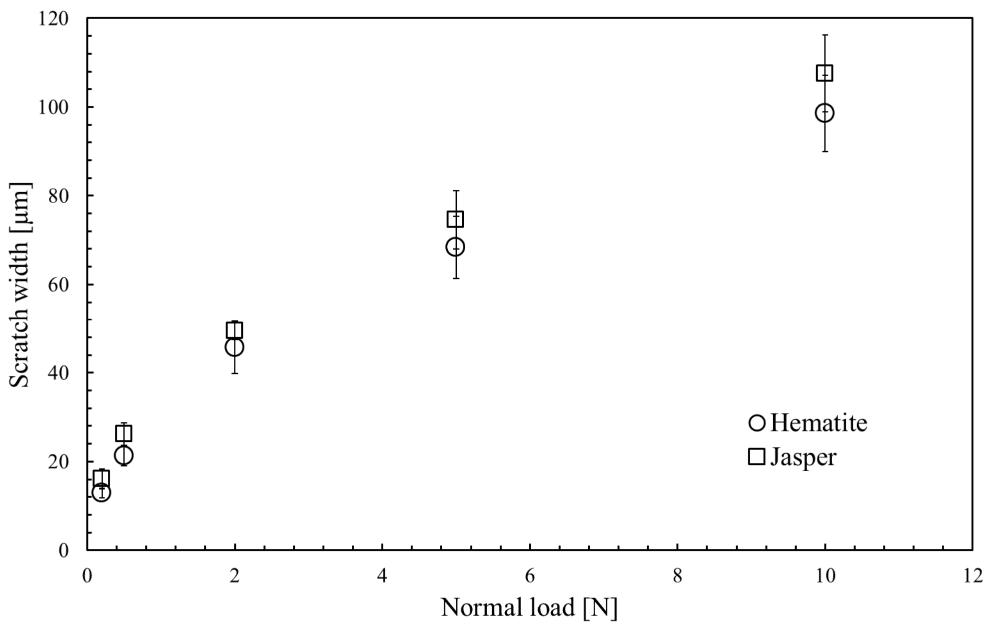

Figure 7. Influence of normal load on scratch width (Vickers indenter).

4. CONCLUSIONS

The main conclusions of this paper are:

1. Jasper presented the most brittle character and hematite light phase the less.
2. The proximity with quartz veins reduces the transition loads for both minerals.
3. The critical transition loads are lower in the tests performed with Vickers indenter.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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