



# TECHNICAL MEMORANDUM

14. August 2009

**TO: Clients and Laboratory Contractors of DJB Consultants Inc**

**FROM: DJB Consultants, Inc.**

**SUBJECT: Crushing Work Index Comparisons Between Labs**

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## Summary

It has come to the attention of DJB Consultants, Inc. that a practitioner of mineral comminution is questioning the Bond Low Energy Impact Crushing Work Index ( $W_{iC}$ ) results of a particular laboratory. It appears that this is based on a presumption that the DWI results of a SMC tests can be used as a proxy for  $W_{iC}$ .

DJB Consultants, Inc. believes this assumption is false in general, but can be locally true for particular ore types. Because the underlying assumption is generally false, the conclusion “there is a bias in results of labs” is also believed to be false.

## Relationship between $W_{iC}$ and DWI

Both tests are crushing tests. DWI samples are tested at a variety of sizes then averaged to give a single result for, effectively, one size: 31 mm diameter<sup>i</sup>. Bond crushing work index test are performed at a coarser size, at least 75 mm<sup>ii</sup> (though use of HQ core results in two dimensions being less than that requirement, about 65 mm). The two tests should only show a relationship if there is no intervening texture between the 31 mm and 65-75 mm size classes.

DJB Consultants Inc. has been involved in several projects where comparable samples have been taken for the Bond suite of tests (crushing, rod mill and ball mill) and SMC tests (DWI)<sup>iii</sup>. The following Figures 1 through 6 show comparison of DWI versus  $W_{iC}$  for ore types from various porphyry projects in North, Central and South America. The small grey points indicate the whole Millpower 2000 database, and the bold red points indicate the ore in question. The Millpower 2000 database has 335 comparable points covering 10 different projects for DWI and  $W_{iC}$  (and 420 points covering 18 projects if  $A \times b$  is substituted for DWI – similar correlations are observed using  $A \times b$ ).

The units of measure are different in the two tests:  $W_i$  values are energy per mass, whereas DWI is energy per volume. Comparing values across projects requires accommodation of this mass/volume difference. The density difference is neglected in Figures 1 through 6 as density differences are small within each ore type (red points).

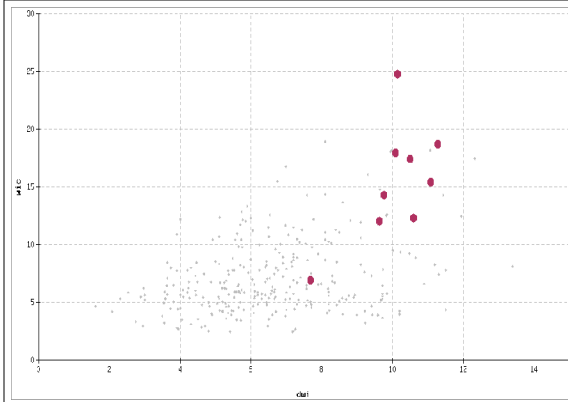


Figure 1:  $W_c$  v DWI for Ore Type 1 at Porphyry Project #1 in the Americas

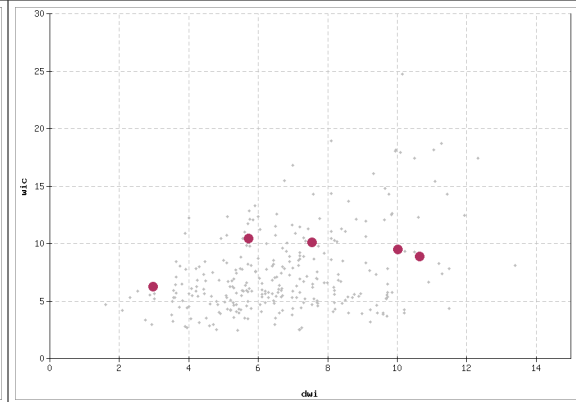


Figure 2:  $W_c$  v DWI for Ore Type 2 (contains significant magnetite) at Porphyry Project #1

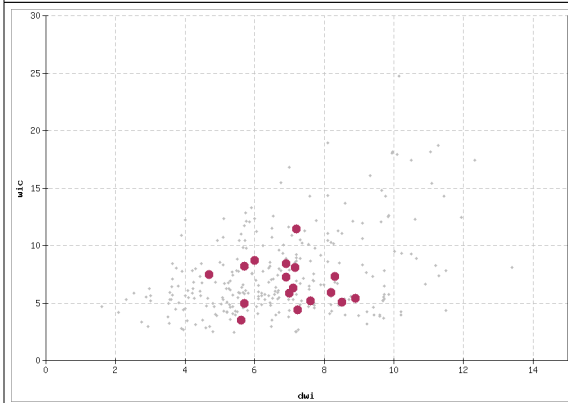


Figure 3:  $W_c$  v DWI for Porphyry Project #2 in the Americas

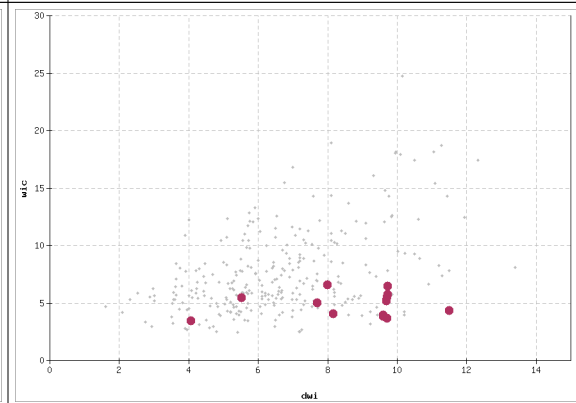


Figure 4:  $W_c$  v DWI for Porphyry Project #3 in the Americas

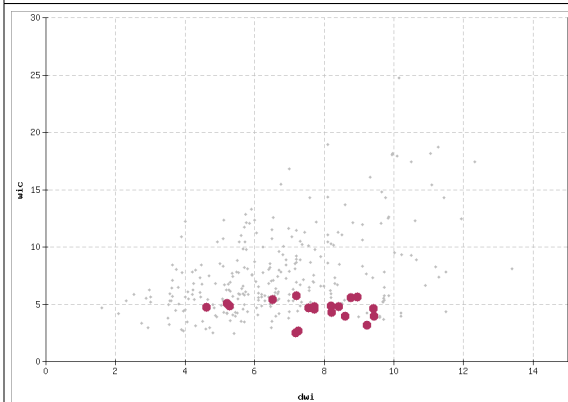


Figure 5:  $W_c$  v DWI for a Second Ore Type at Porphyry Project #3

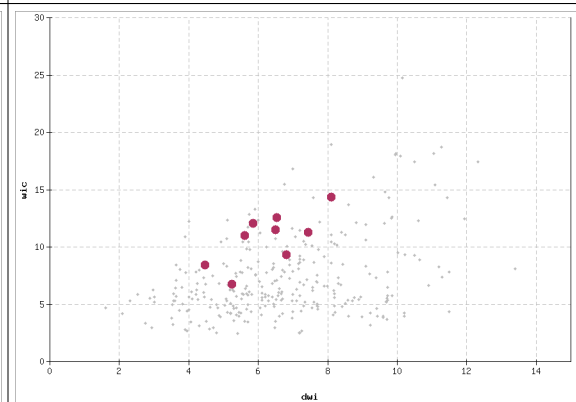


Figure 6:  $W_c$  v DWI for Porphyry Project #4 in the Americas

The only example that appears to show a positive correlation between DWI and  $W_c$  is Figure 6. All of the  $W_c$  tests in the Figures 1-6 were performed at the same laboratory in the USA. The DWI tests were performed at laboratories in Canada and Chile.

The conclusion the author draws from this series of Figures is that there is no generalised relationship between  $W_c$  and DWI, though individual projects may show local relationships.

## Texture and Fractures

When run on porphyry projects in the Americas, the  $W_{iC}$  test is generally measuring the strength of fractures in the rock. Porphyry deposits are heavily cross-cut with fractures creating the stockwork of veins that is characteristic of the deposit type. Depending on the project, the fracture spacing can be less than 75 mm (the size of a  $W_{iC}$  test specimen) but greater than 31 mm (the average size of a SMC test specimen).

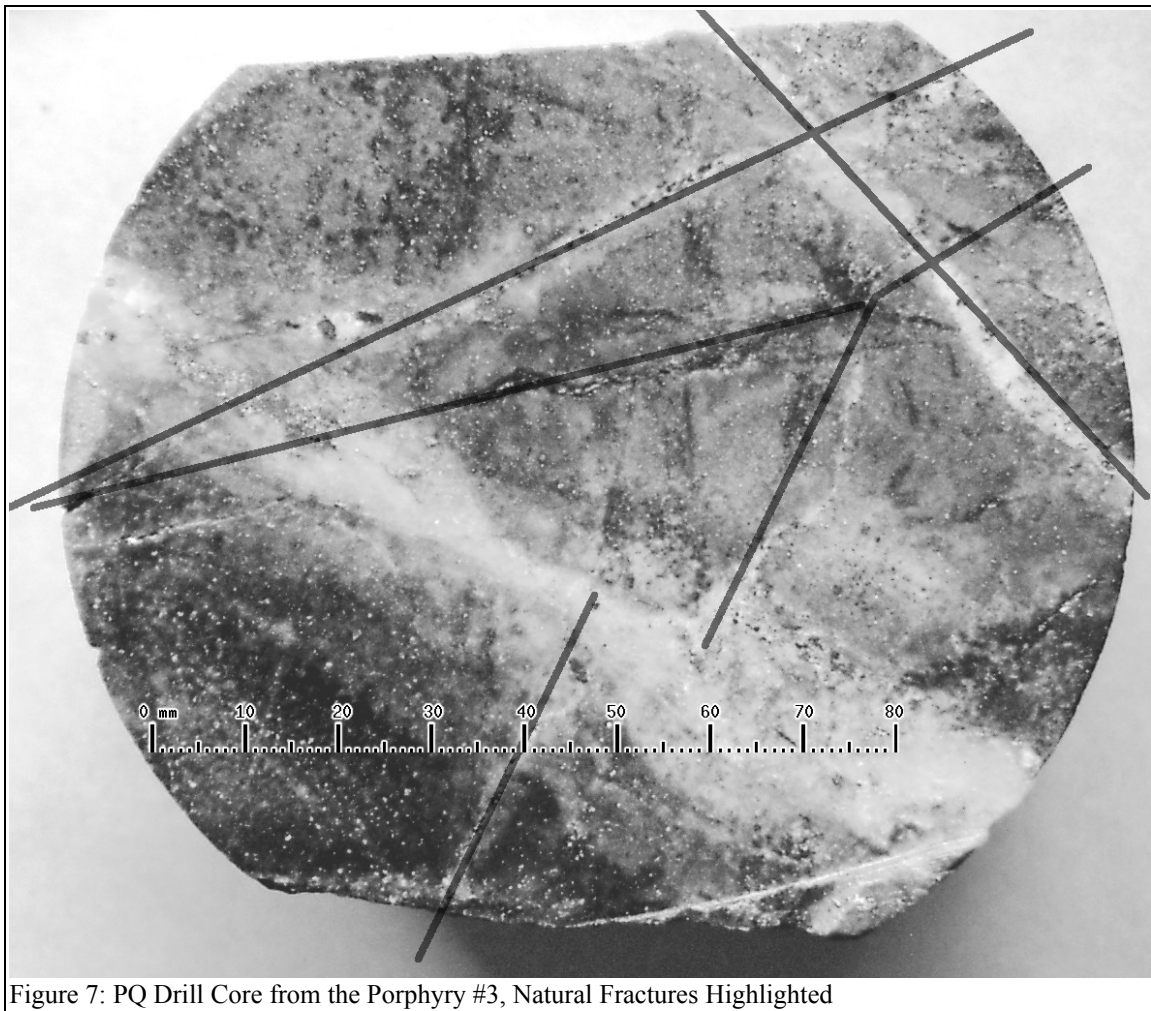


Figure 7: PQ Drill Core from the Porphyry #3, Natural Fractures Highlighted

The drill core in Figure 7 is from the same ore type as Figure 4. The spacing between highlighted natural fractures in the rock generally exceed 40 mm in two dimensions, thus an SMC test conducted on this sample would return the energy required to break the matrix of the rock. A  $W_{iC}$  test on this sample will return a much lower energy because it will report the energy required to break the highlighted fractures. The fracture strength is usually dictated by geometry, fracture spacing and nature of infilling (clay versus quartz, healed versus open, etc). There is usually no relationship between the strength of the matrix of a rock and the strength of fractures in a rock; therefore, one expects no

relationship between DWI and  $W_{iC}$  when a rock's fracture spacing manifests between the two sample sizes.

Homogeneous ore types with fewer fractures are more likely to show a relationship between DWI and  $W_{iC}$ , just as ball mill work index ( $W_{iBM}$ ) can sometimes be related with  $W_{iC}$ . Examples of these ore types are Australian & Canadian Shield gold and nickel ores.

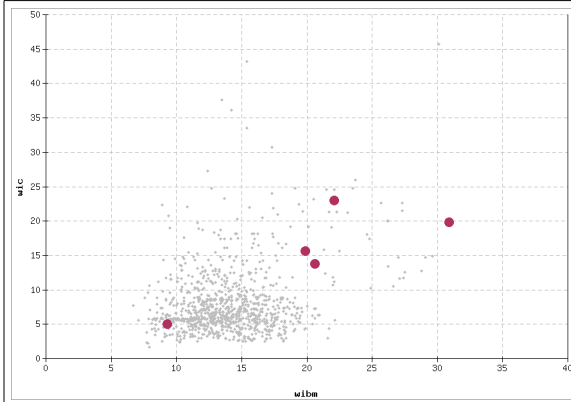


Figure 8:  $W_{iC}$  v  $W_{iBM}$  for a Canadian Nickel Ore

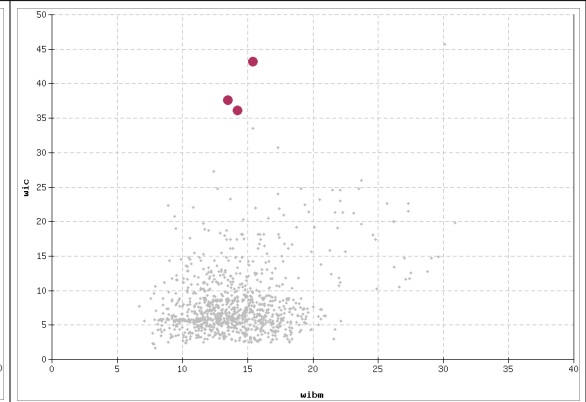


Figure 9:  $W_{iC}$  v  $W_{iBM}$  for an Australian Nickel Ore

Appropriate Comparisons for DWI

The sample dimensions and porphyry rock textures make DWI inappropriate to compare to  $W_{iC}$ . It is better to compare DWI to the rod mill work index ( $W_{iRM}$ ). The sample dimensions of the rod mill work index (13 mm) is slightly smaller than an SMC sample but we don't usually observe textures at sizes between the two tests. It is DJB's experience that the DWI, rod mill work index and SPI tend to correlate well.

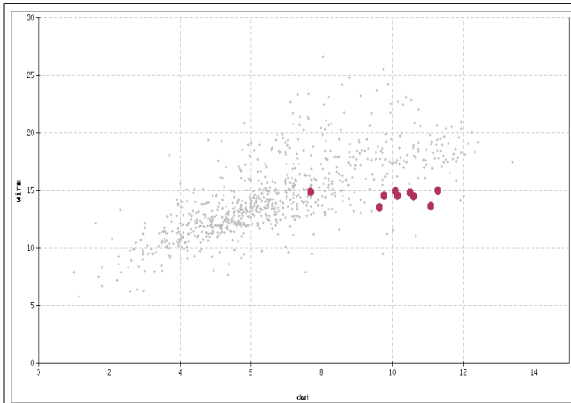


Figure 10:  $W_{iRM}$  v DWI for the Same Ore as Figure 1

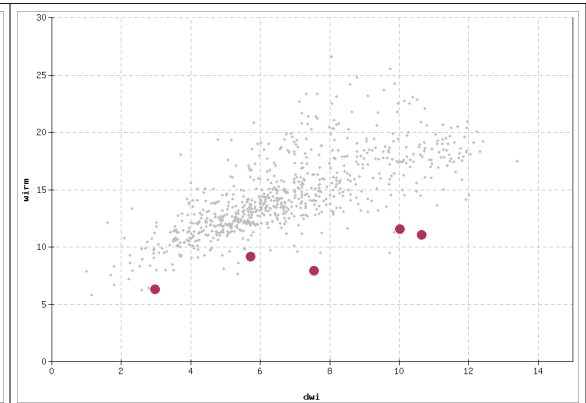


Figure 11:  $W_{iRM}$  v DWI for the Same Ore as Figure 2

Figure 11 shows a positive relationship between  $W_{iRM}$  and DWI, but the ore (bold, red points) is offset from the database (small, grey points). This ore type has a high density relative to the other deposits in the database. As mentioned earlier, DWI has a volumetric basis and  $W_i$  has a mass basis, so this offset is normal and expected.

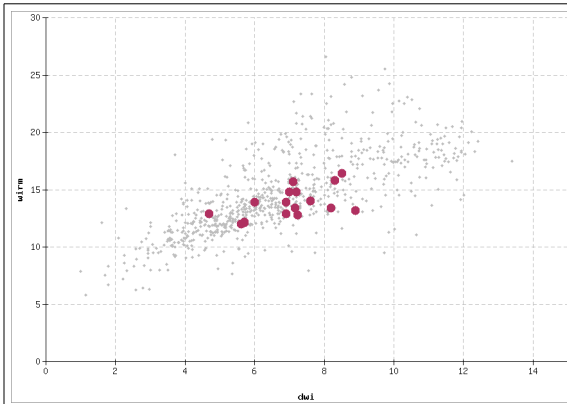


Figure 12:  $W_{IRM}$  v DWI for the Same Ore as Figure 3

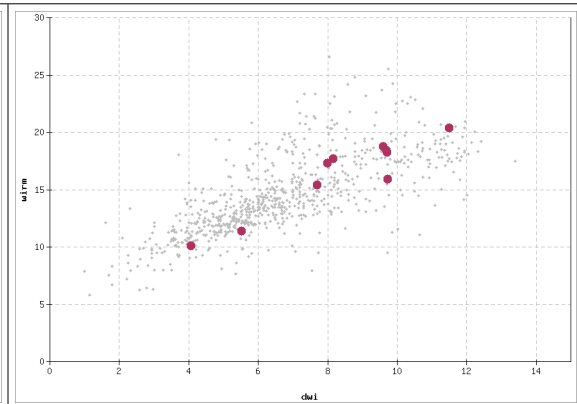


Figure 13:  $W_{IRM}$  v DWI for the Same Ore as Figure 4

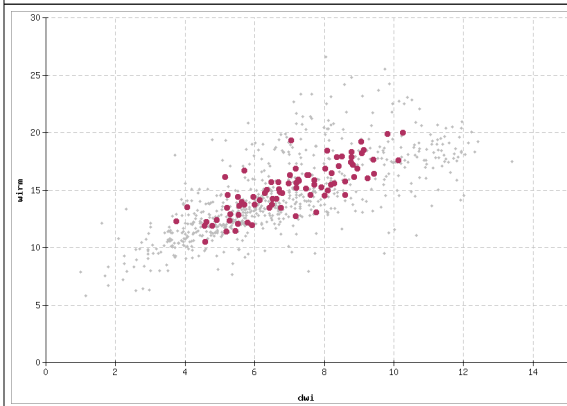


Figure 14:  $W_{IRM}$  v DWI for the Same Ore as Figure 5

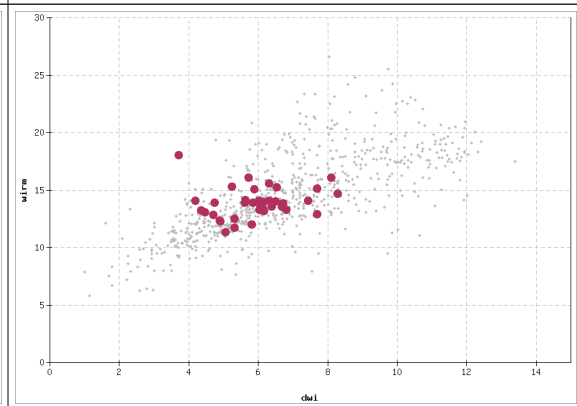


Figure 15:  $W_{IRM}$  v DWI for the Same Ore as Figure 6

Additional observations about sample size have been presented in a paper by Andre McKen et al. at the SAG 2006 conference<sup>iv</sup>.

### Conclusion

- There is generally no relationship between crushing work index and DWI in highly fractured samples.
- Porphyry projects in the Americas tend to be highly fractured.
- The comparison of  $W_{IC}$  values between different laboratories cannot be conducted using DWI as a “normalising” (proxy) value.
- The only valid comparison of  $W_{IC}$  values between different laboratories is to use subsamples of the same material in both laboratories.
- The statement that one particular laboratory “reports low values” based on a comparison of different ores of different densities that are normalised using DWI results is false.

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- i *Design of AG/SAG Mill Circuits Using the SMC Test*, Steve Morrell, SAG 2006 Proceedings, Pg IV-291
  - ii *An Overview of the Small-Scale Tests Available to Characterise Ore Grindability*, Andre McKen & Steve Williams, SAG 2006 Proceedings, Pg IV-317
  - iii *Testwork Programs That Deliver Multiple Data Sets of Comminution Parameters for Use In Mine Planning and Project Engineering*, Derek Barratt & Alex Doll, Proceedings of Procemin 2008
  - iv *Digging Into A Large Testing Database*, Andre McKen, François Veret & Steve Williams, SAG 2006 Proceedings, Pp IV-331 to IV-346.