Innovations in Comminution

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Today’s presenters

Presenters:

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Agenda

1. Why focus on comminution?
2. Greg Lane – Autogenous milling technologies
3. Bianca Foggiatto - Stirred milling in coarse duty applications
4. Grant Ballantyne - Fractal Energy methodology
5. Key takeaways
6. Q&A

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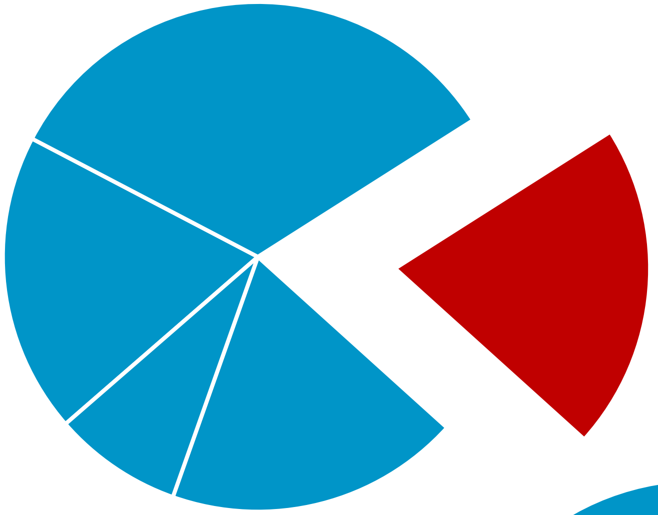
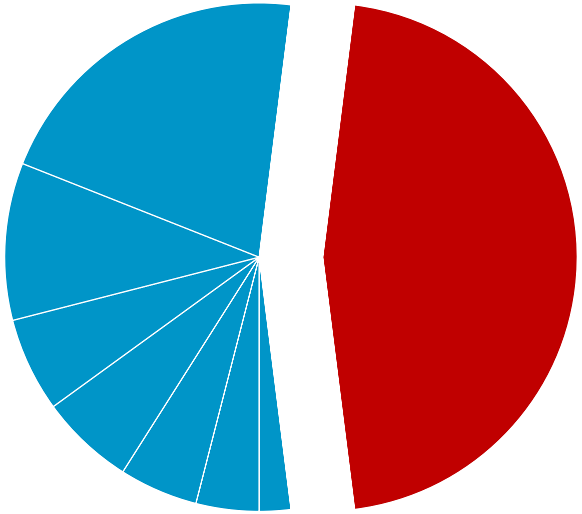
Why focus on comminution?

Capex

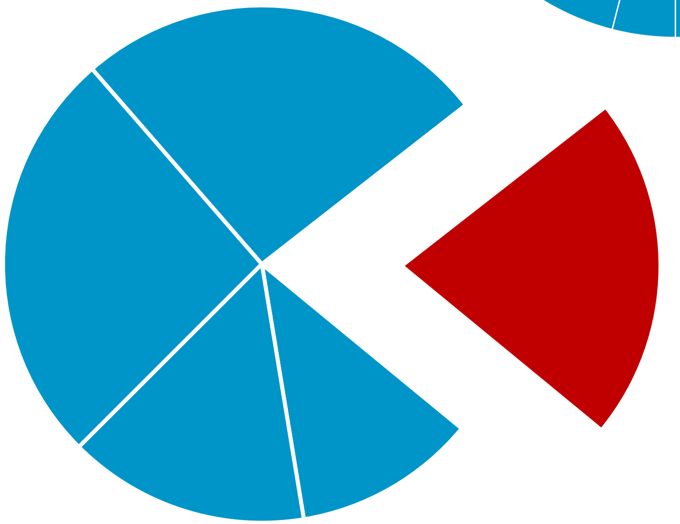


Energy



Water

Opex



Tailings

1

Autogenous milling technologies

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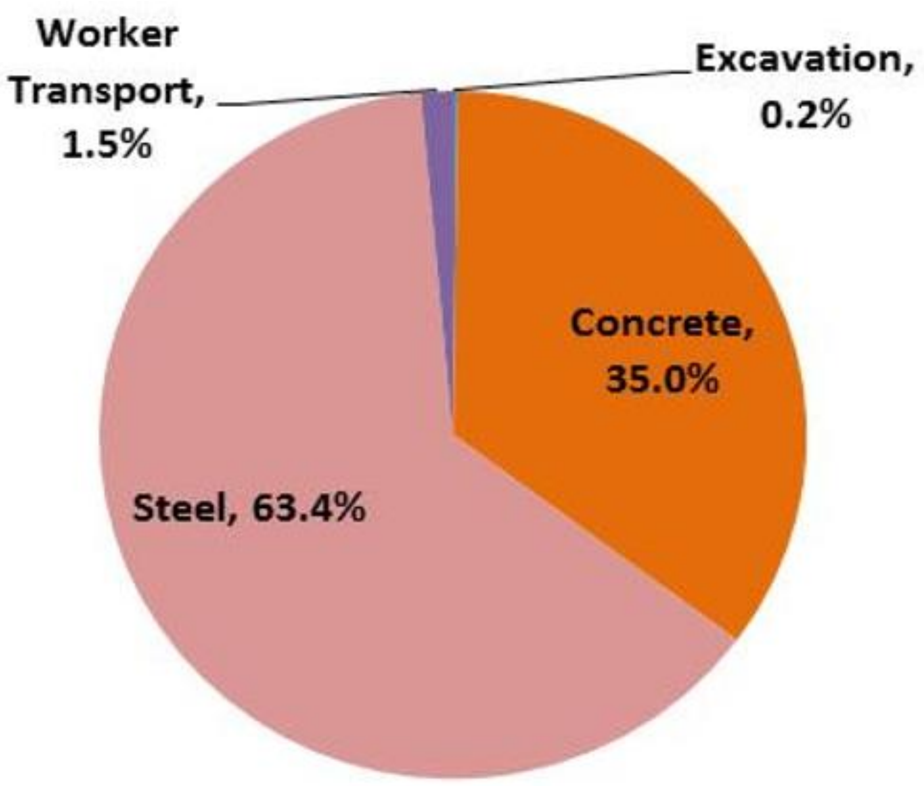
CO_2 production metrics

- Most of the CO_2 production associated with plant construction is associated with concrete and steel consumption.
- Typical 4 Mt/y plant has 3000 m^3 concrete and 1400 t steel.
- Footprint optimisation and good design save up to 30% on steel and concrete.
- The total CO_2 emissions related with plant construction are equivalent to **7 to 10 weeks steel media consumption** in an operating plant.

75 kt/d Cu concentrator



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What is conventional wisdom for a 4 Mt/y plant?

SAB(C) circuit (SAG and ball mills, possibly with pebble crushing)

- High steel consumption, say 1 to 1.5 kg/t balls.
- Moderate energy efficiency, say 1.2 x Bond test work standard.
- Low to moderate capital cost, say A$3M/MW.
- Moderate operating cost, say A$4/t, depending on product size and abrasiveness.
- Simple to operate.

Google Earth – Carrapateena 22 June 2023

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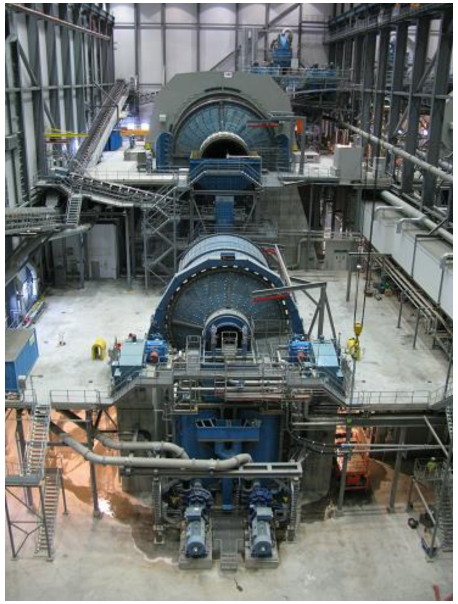
Autogenous milling technologies






- Dry compression crushing to fine sizes using Vertical Roller Mills or High Pressure Grinding Rolls, e.g Iron Ridge.
- Autogenous primary and secondary milling e.g. Aitik, Forrestania.
- Single stage autogenous milling, e.g. Olympic Dam, Kambalda.
- Autogenous primary mills and secondary ball milling, e.g. Savage River, Ridgeway.

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Flowsheet and efficiency implications

Moderate competence and hardness ore – 4 Mt/y plant

Technology	Classification	Media Type & Consumption	Energy Efficiency - grinding	Energy Efficiency - classification	Operating Cost	Capital Cost	CO_2 Production
VRM or HPGR	Dry air sep.	Tyre wear - low	0.5 to 0.6	0.1 to 0.4	0.6 to 1	1 to 1.4	Low
AG and pebble milling	Wet cyclone	Liner wear – very low	1.0 to 1.2	0.1	1	1.1	Low
Single stage AG milling	Wet cyclone	Liner wear – very low	1.0 to 1.2	0.15	1	0.9	Low
AG and ball milling	Wet cyclone	Balls in ball mill - high	1.0 to 1.25	0.1	1.3	1	Moderate
SAG & ball mill	Wet cyclone	Balls in both mills	1.0 to 1.25	0.1	1.6	0.9	High

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Constraints

- VRM and HPGR milling – cost of fine dry classification
- AG milling
  - Requires improved definition of ore body characteristics
  - Higher capex
  - More complex to operate if ore is variable

Opportunities & advantages

- Coarse particle flotation reduces reliance on high-cost air classifiers.
- Aitik and Olympic Dam are Q1 operating cost projects.
- As CO_2 emissions reductions are now important, autogenous options are being reconsidered.
- Improved geomet methods mitigate unexpected performance variation.

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Stirred milling in coarse duty applications

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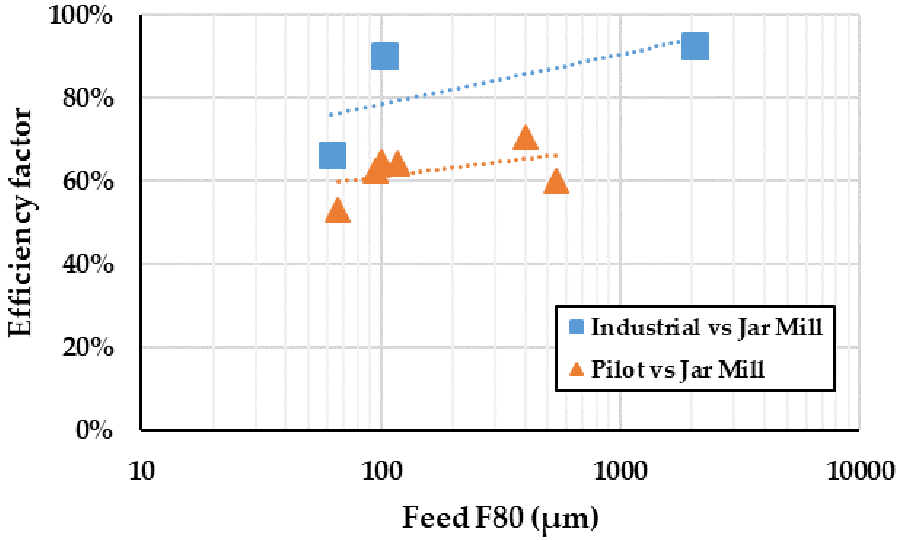
Introduction

- Stirred milling technologies are commonly used for regrinding duties to achieve improved energy efficiency
- Due consideration must be given to media size selection
  - feed slurry density
  - target product size
- The use of larger media to effectively break down larger particles is required in coarser duty applications



Source: Huang at al., 2019

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Stirred milling – ESG context

Stirred milling in the greenhouse gas emission reduction context:

Scope 2 emissions - related to electrical energy use

- higher energy efficiency

Scope 3 emissions - relate principally to consumables production & transportation

- media embedded footprint
  - 0.3 tons of CO_2 per ton of ceramic produced
  - 1.4 tons of CO_2 per ton of steel produced
- media transportation
  - ~40% less volume to be transported due to lower wear rate of ceramic media

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Stirred milling in coarse duty applications

Recently, stirred mills are being incorporated in coarse duties in flowsheets featuring SAG mills or HPGRs

- require a controlled top size
- due consideration needs to be given to energy efficiency at coarser duty
- may benefit from an intermediate ball milling stage (tertiary duty)

Vertimill (Metso:Outotec)

Vertical Regrind Mill – VRM

Vertical Power Mill – VPM

(STM Minerals)

IsaMill (Glencore)

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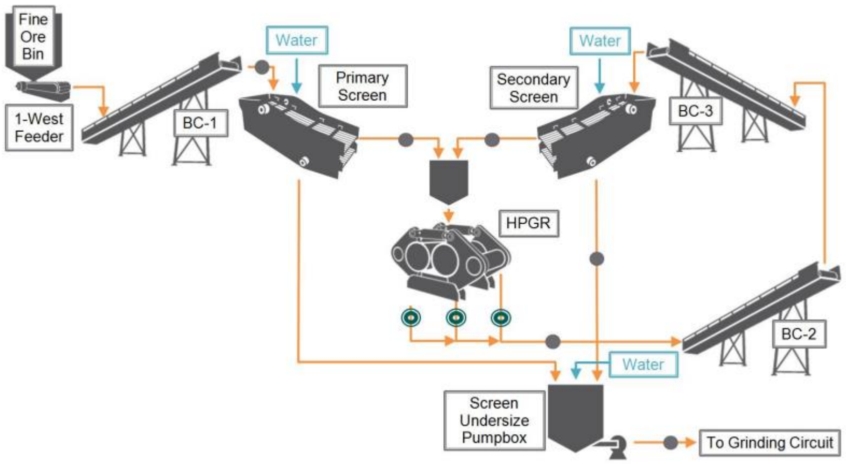
Stirred milling in coarse duty applications - operations

- Morenci (HPGR-VTM)
  - Pilot plant incorporating
    - HRC 3000
    - VTM 650



Source: Knorr et al, 2013

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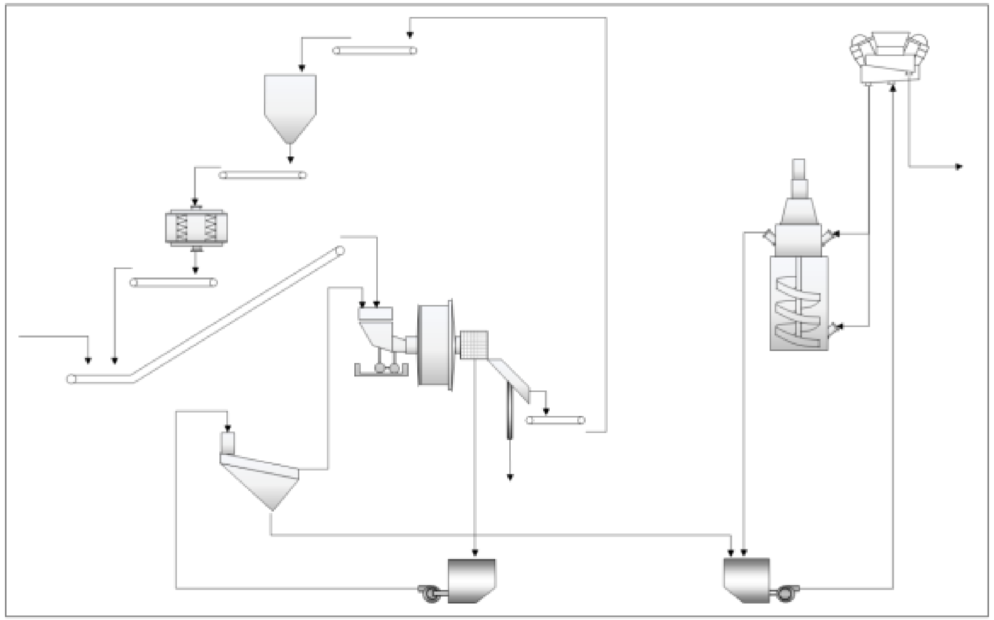
Stirred milling in coarse duty applications - operations

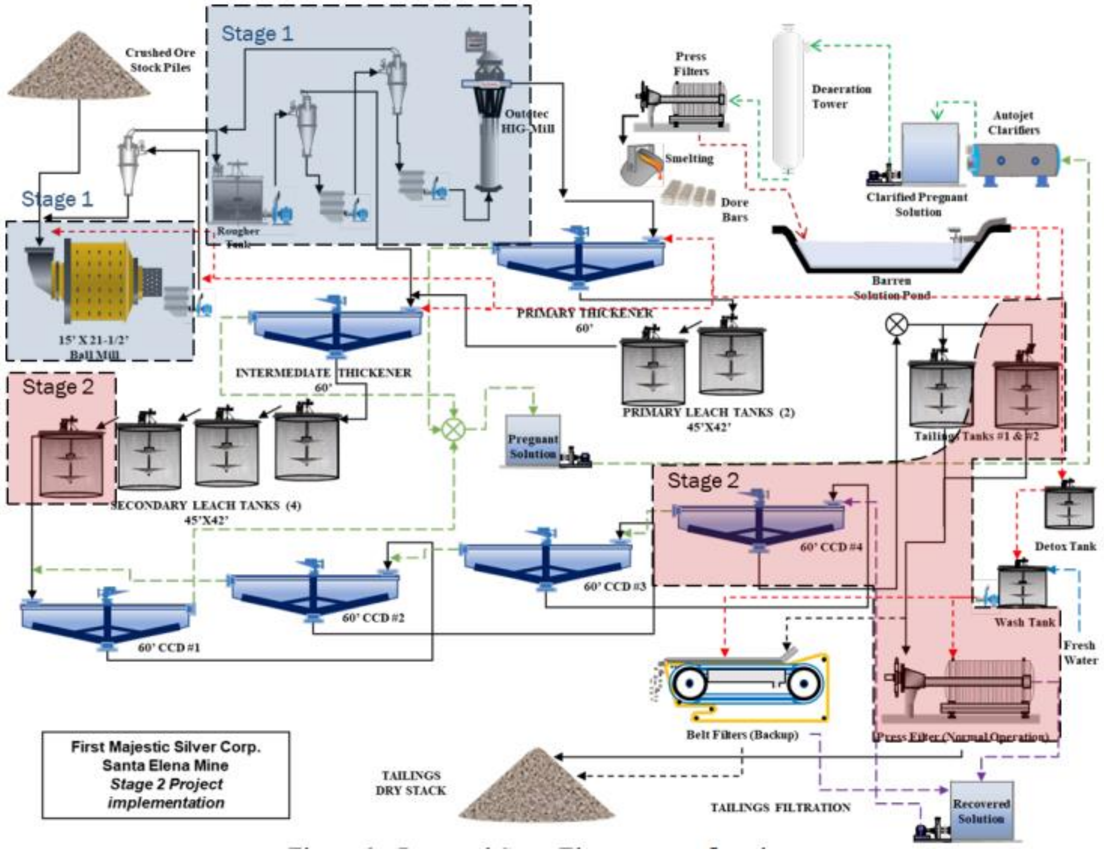
- Boungou (SAG-VTM-C)



Source: Houde & Boylston, 2019

- Other examples include Cadia, Semafo, New Afton, Raglan, Chino, Cannington and Tambomayo

- Santa Elena (3CB-HIG)



Source: Mezquita et al., 2023

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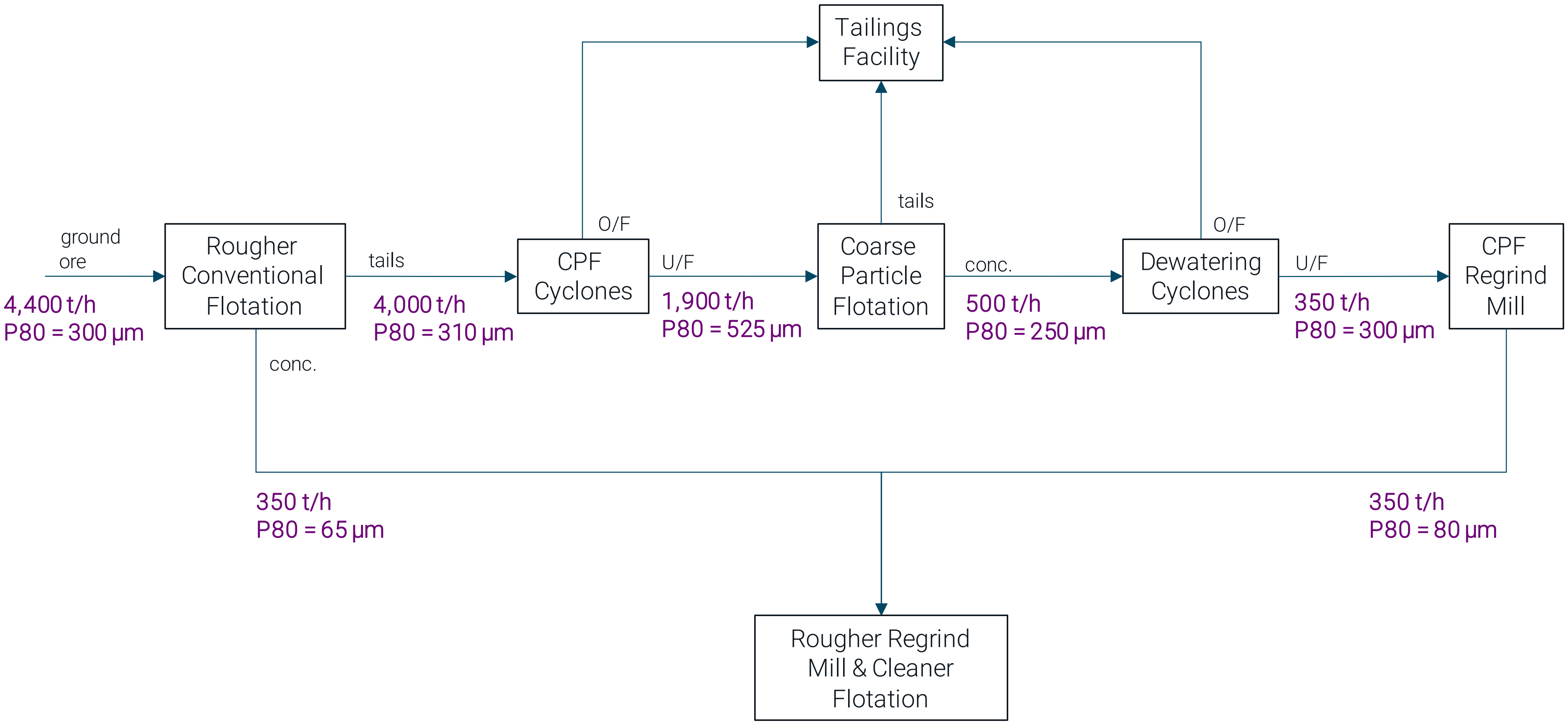
Stirred milling in coarse duty applications – CPF study

Coarse Particle Flotation (CPF) flowsheet treating rougher flotation tailings



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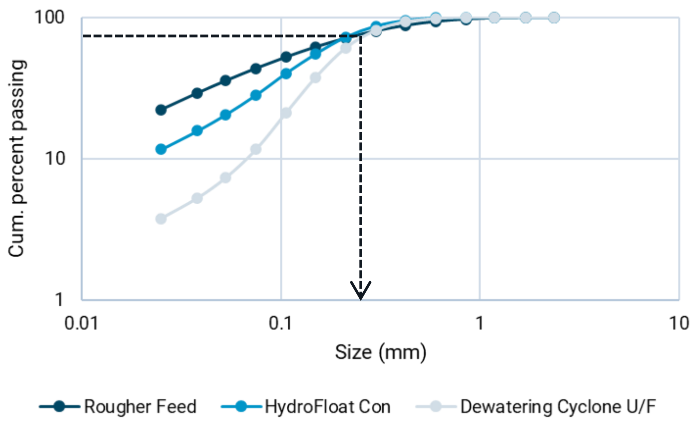
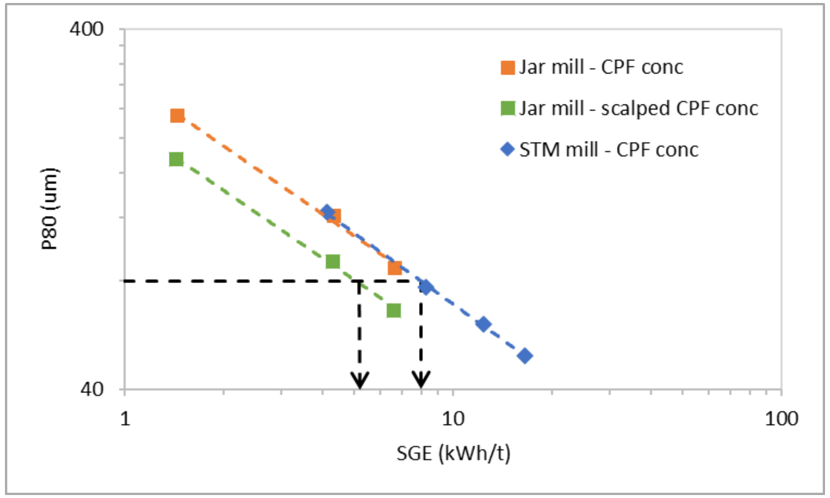
Stirred milling in coarse duty applications – CPF study

- Coarse Particle Flotation (CPF)
  - CPF & dewatering cyclones prior to regrind stage
    - change of particle size distribution slope in log-log space
    - single size measurement (P80) cannot be used for mill sizing purposes
  - presence of fines affect the regrind response (specific energy)
    - however, reduction in specific energy is proportional to the scalping of fines
      - ~30% mass split to cyclone U/F
      - ~30% less energy intensive for same P80





Source: Foggiatto et al, 2023

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Key takeaways

- The use of stirred milling in innovative flowsheets is gaining attention particularly for coarse duty application

- The energy efficiency in these applications depends on
  - regrind feed particle size distribution & slurry pulp density
  - media size selection

- Evaluation of circuits featuring CPF is more challenging
  - CPF regrind feed is typically fines deficient (CPF and dewatering stages)
  - Single size measurement (P80) to represent size distributions does not take into consideration the change in PSD slope
  - Testwork suggest that the regrind energy reduction is proportional to the dewatering stage mass rejection to fines

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Fractal Energy

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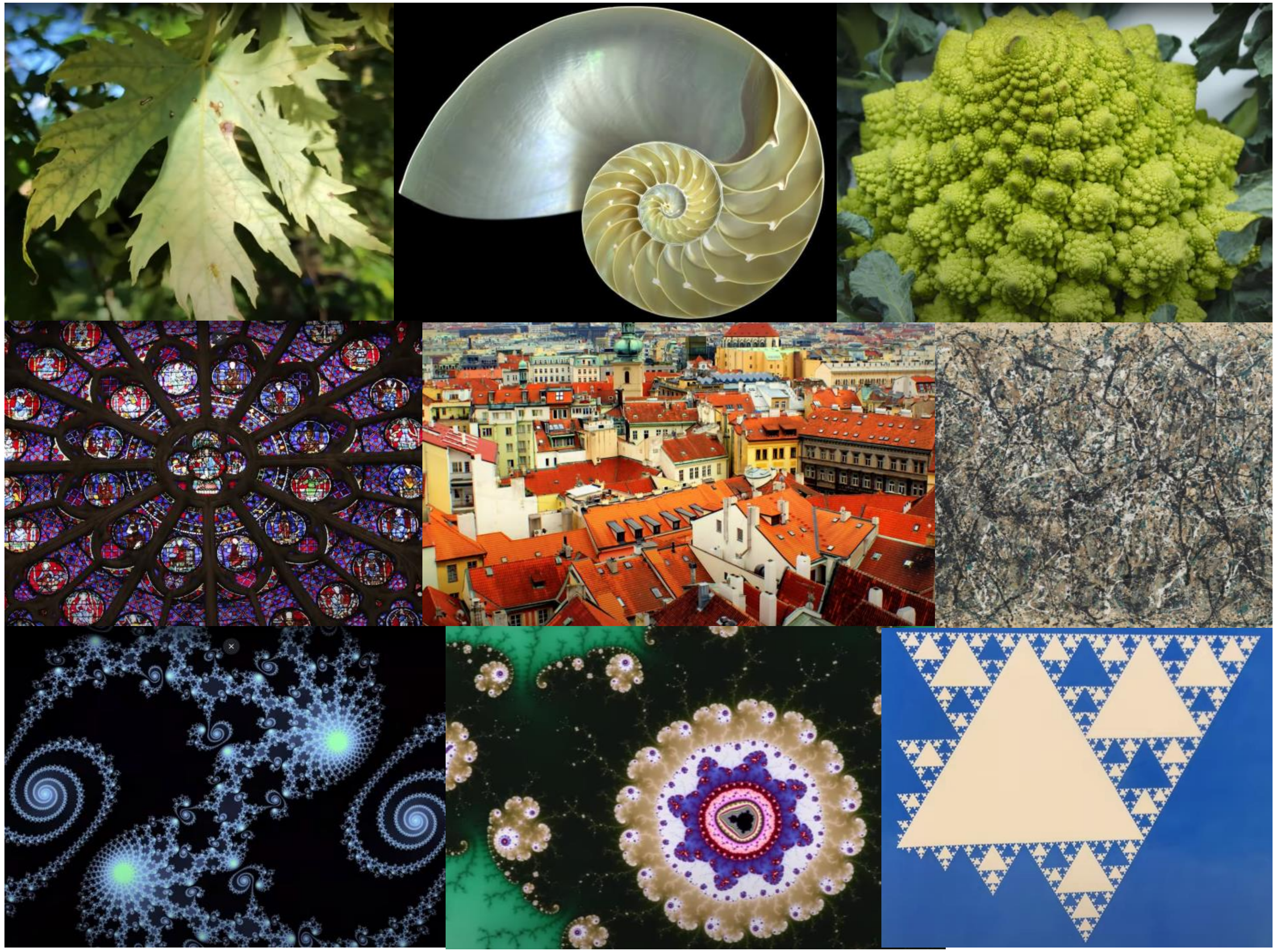
What is a fractal? And how is it useful?

- *“The experience of humanity has always been that there are some shapes which have the peculiar property where each part is like the whole, but smaller”* - Mandlebrot.
- Seen in the natural world, art and mathematics.
- The fundamental geometry of fractals can be described mathematically in terms of their fractal dimension.



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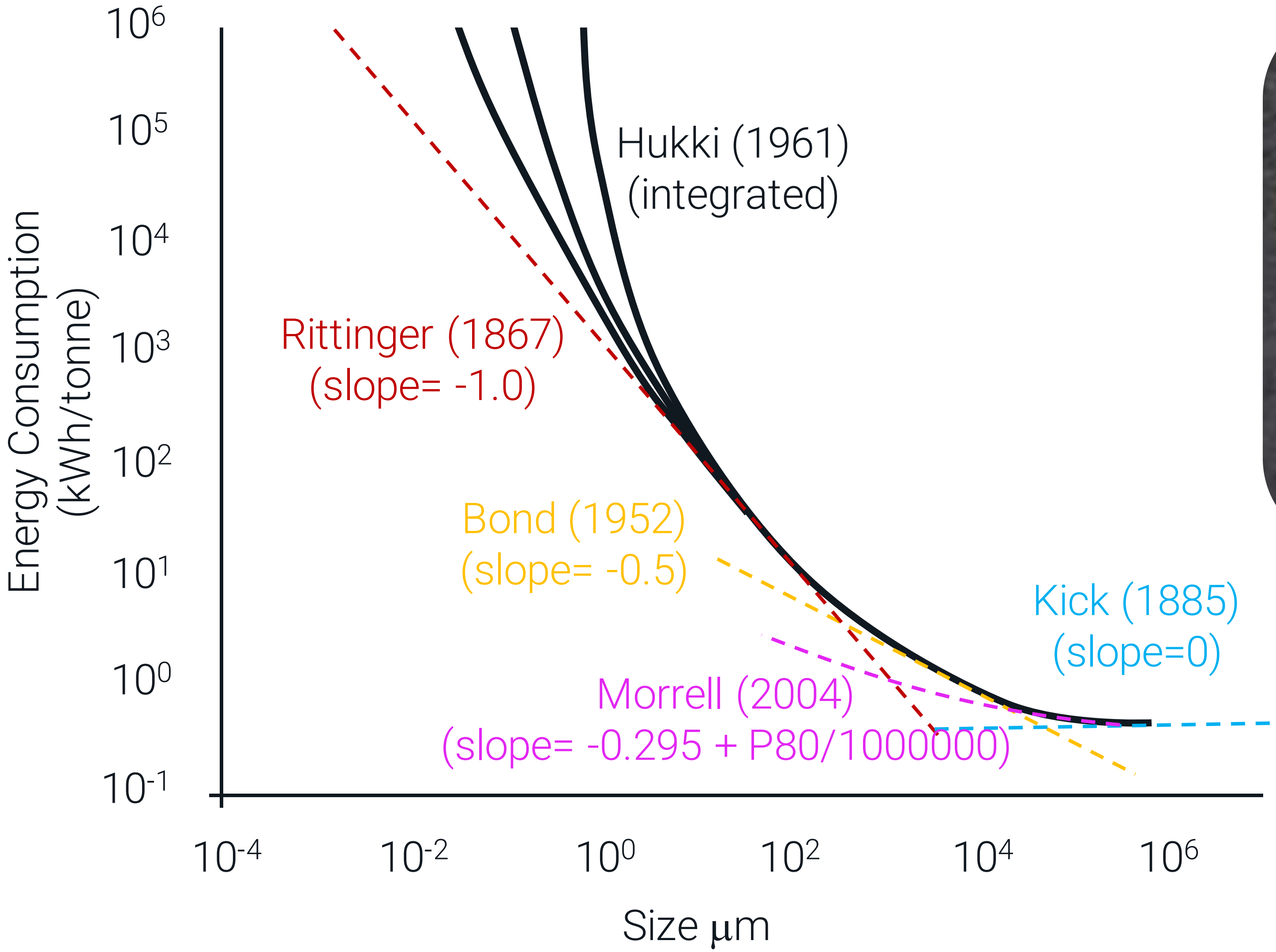
The science of making big rocks smaller



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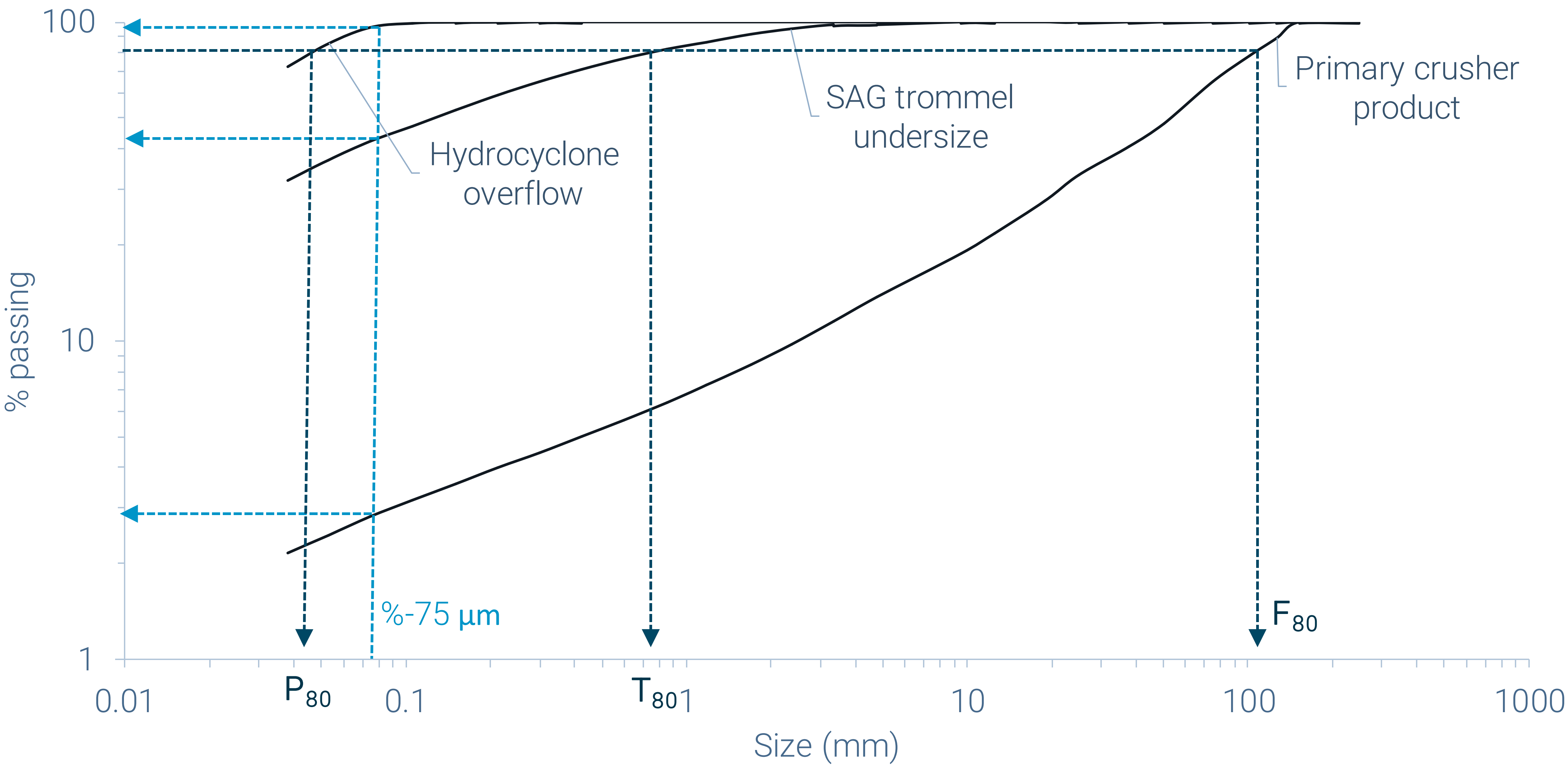
Description of size distributions are the key



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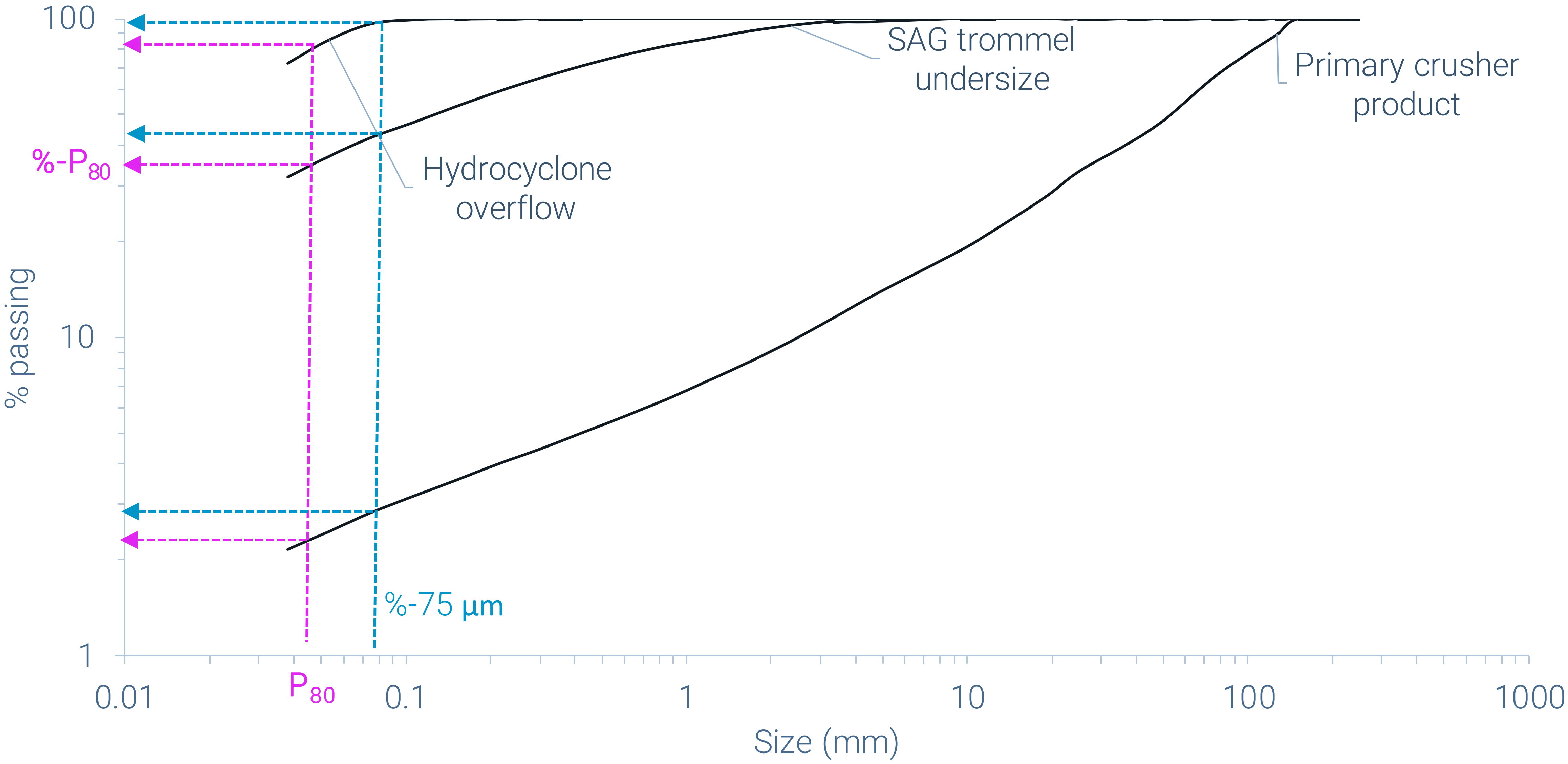
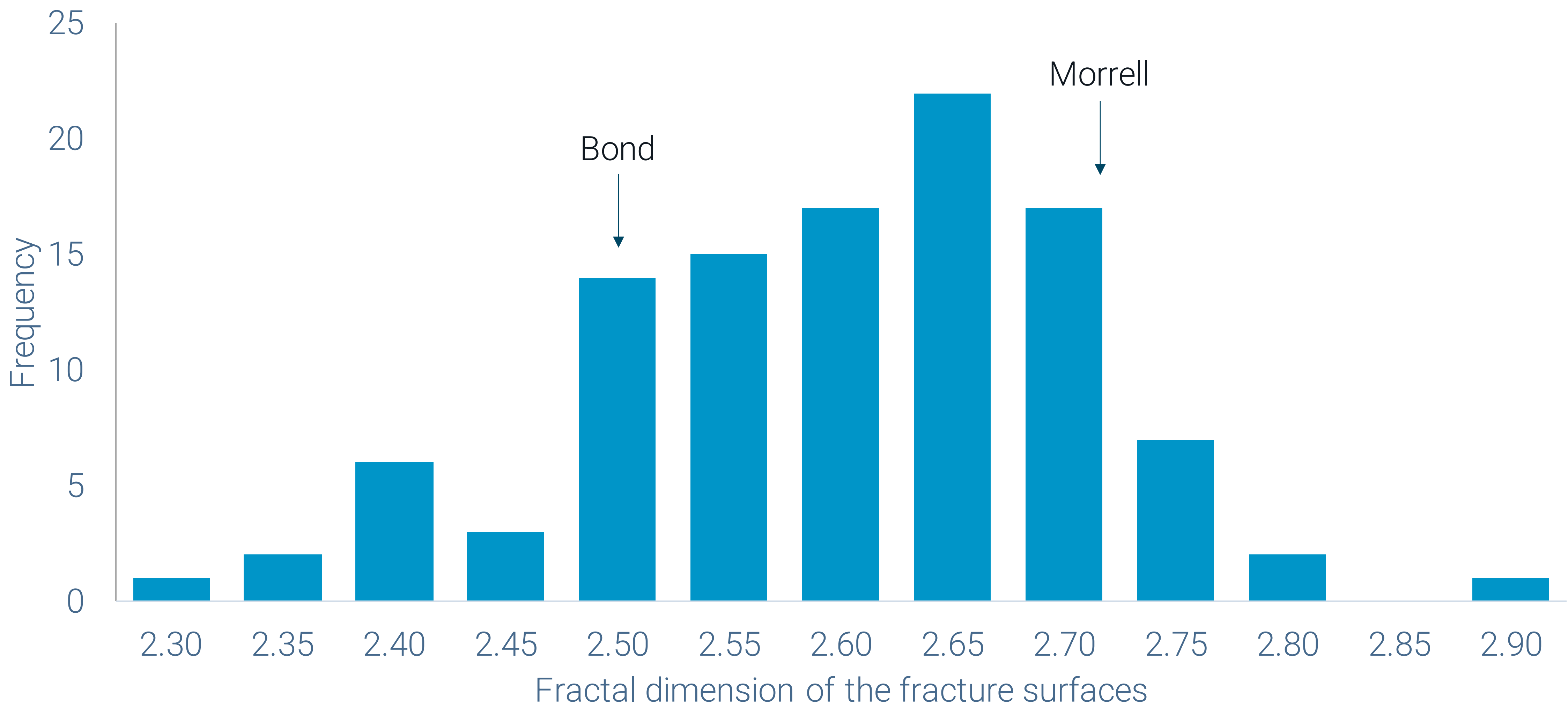
There is no magic in 75µm



Fractal dimension - all datasets



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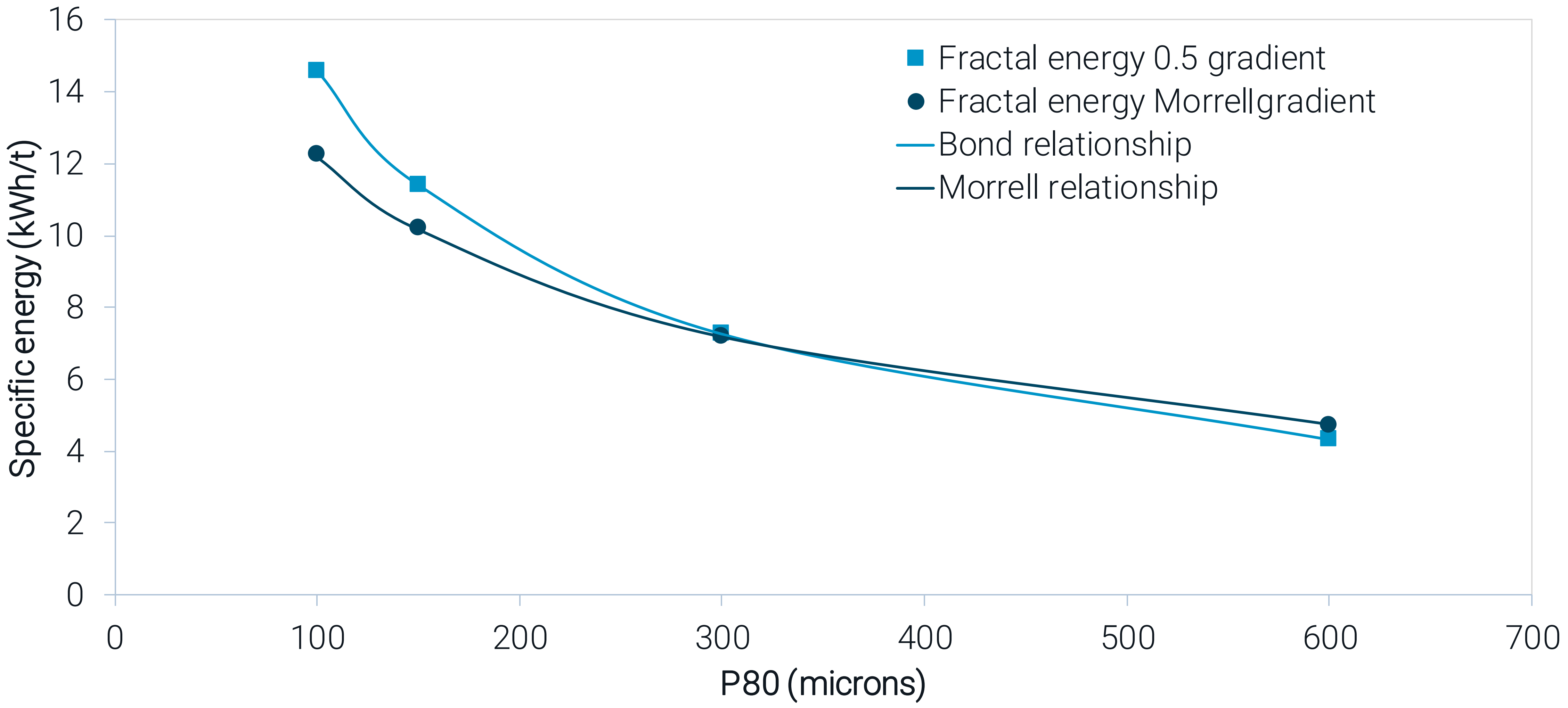
Fractal Energy can unify current approaches



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Conclusions

1. Fractal Energy predicts full size distributions by combining:
   - SSE to determine the efficiency of fines production
   - Fractal dimension to determine the transformation of the gradient of the feed size distribution to the product
2. The Fractal Energy approach has been shown to be consistent when the ore and breakage environment are similar, and responds logically for different ore-types, equipment and circuit configurations
3. The Fractal Energy approach unites Bond and Morrell into a simple general form to describe the application of comminution energy to transform particle size distributions
4. The approach has proven useful in site optimisation studies, evaluating laboratory results and equipment design

For more details, please see: Ballantyne, G., 2023. Fractal Energy: Combining fractal dimension of fracture surfaces and Size Specific Energy to describe comminution, In Comminution 23, Cape Town, South Africa.

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Key Takeaways

1. Autogenous milling, in various forms, reduces operating costs and CO_2 emissions (scope 3).
2. Stirred media mills can provide an energy efficient solution at coarser feed size distributions.
3. The recently developed Fractal Energy approach unites previous comminution models (Bond, Morrell, etc.) on a simple basis.

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Questions

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