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SELECTIVE FRAGMENTATION AND WATER-FREE PRE-CONCENTRATION FOR SUSTAINABLE PROCESSING OF FE-TI-V BEARING ORES

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WHY SUSTAINABLE PROCESSING OF FE-TI-V ORES MATTERS

- Fe-Ti-V ores (vanadium and titanium) contain critical raw materials for EU energy and industrial sectors (essential for steel alloys, batteries, and renewable energy technologies)
- Conventional comminution is water-intensive and energy-demanding
- Complex ores require improved liberation strategies for efficient separation
- Selective fragmentation supports water-lean and energy-efficient processing and maintain recovery performance

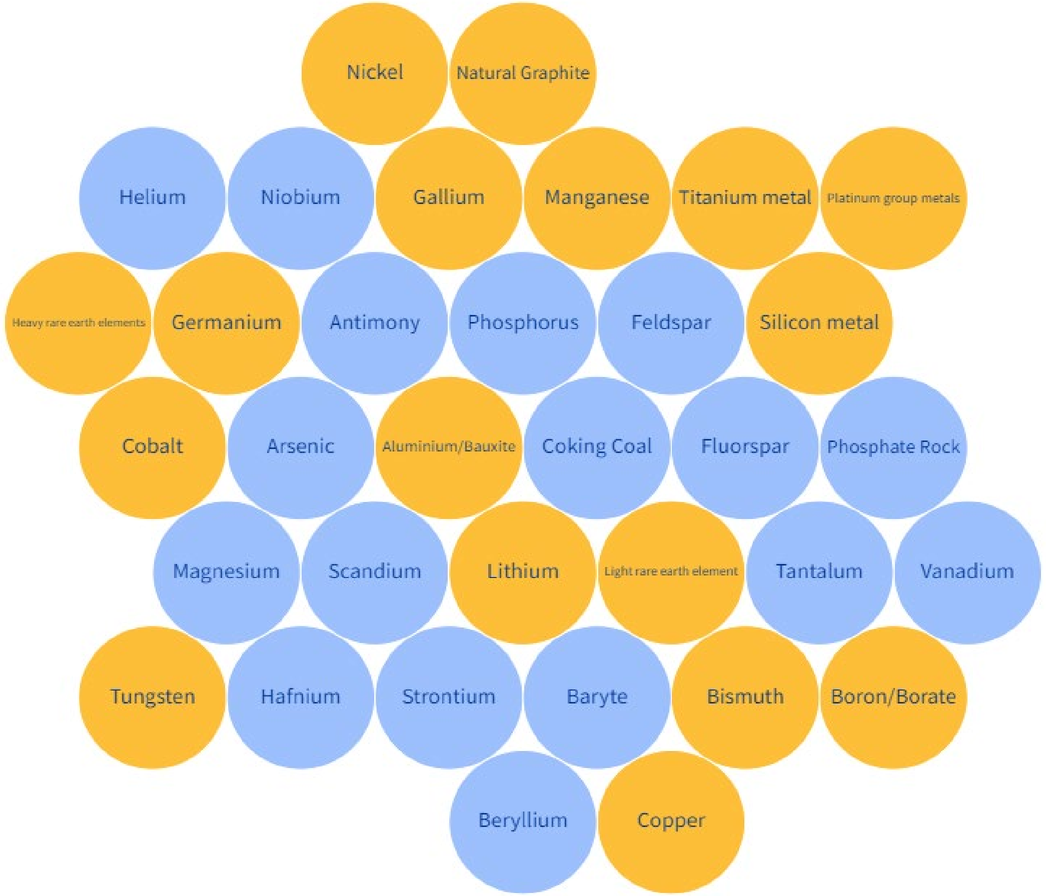

Fig. 1: Infographic – An EU critical raw materials act for the future of EU supply chains, Source: Council of the EU

THE SELECTIVE FRAGMENTATION CONCEPT

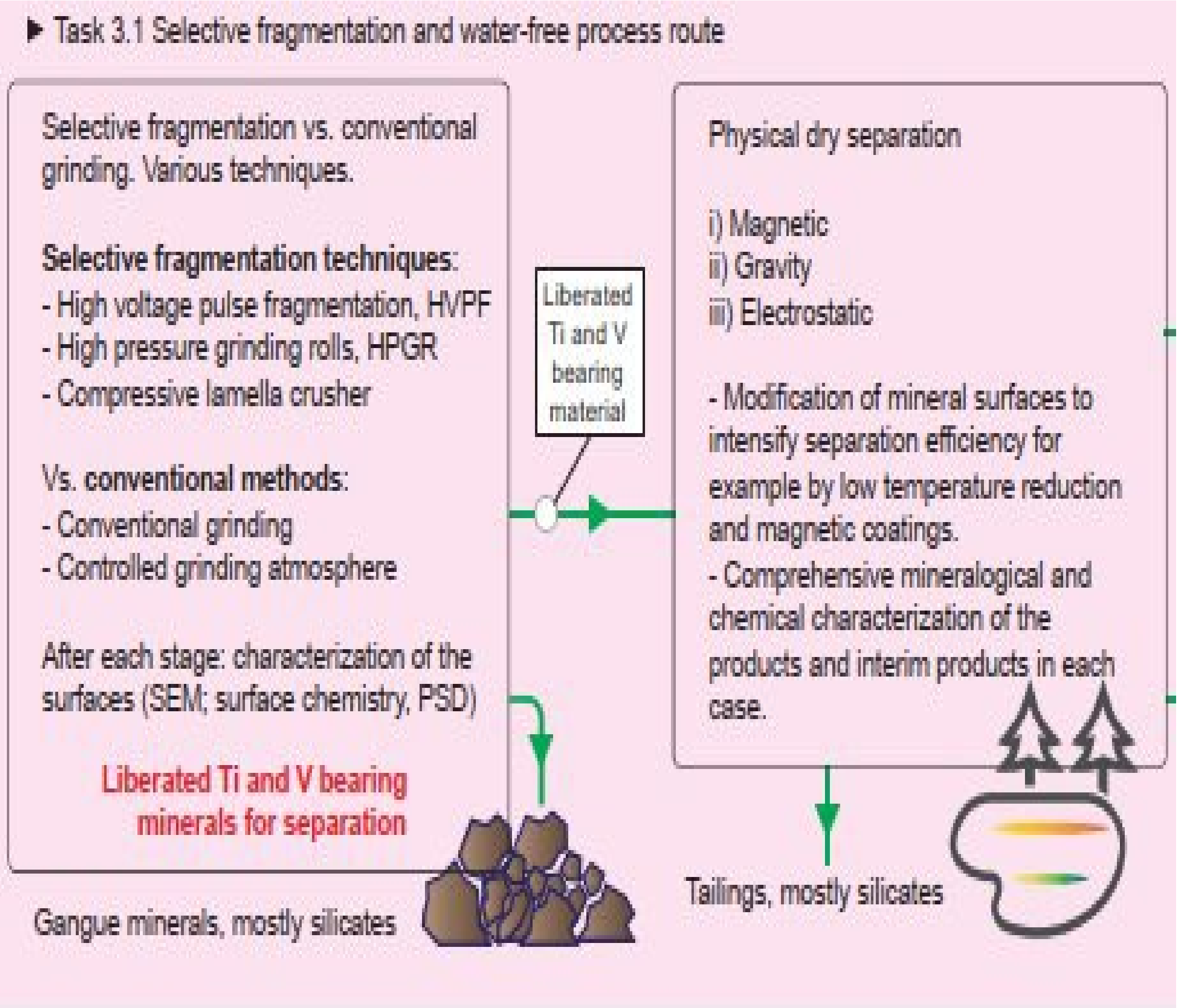

Fig. 2: Selective fragmentation and water-free pre-concentration technologies

- Promotes breakage along mineral boundaries instead of random fracturing
- Produces coarser liberated particles and fewer fines
- Supports less grinding and lower energy
- Improves downstream dry separation efficiency
- Technologies studied:
  - Continuously Compressing Lamella Crusher (CLC) – slow compression, water-free
  - High-Pressure Grinding Roll (HPGR) – interparticle compression, reduced energy use
  - High-Voltage Pulse Fragmentation (HVPF) – electrical disintegration along grain boundaries

EXPERIMENTAL OVERVIEW

Fig. 3: ROTAP Sieve for PSD

- Laboratory tests performed on Fe-Ti-V bearing ores after sorting to middling size (19/9.5mm)
- Particle size distribution evaluated across fractions (with <106 µm as the preferred particle size for preconcentration)
- Specific energy input (Bond Work Index [kWh/t]: Jaw crusher – 19.53, HPGR – 16.28)
- Liberation assessed using Mineral Liberation Analyzer (MLA)
- Minerals of interest: Magnetite, Ilmenite, and Titanite

Item	Mass (kg)
Oversize (>19 mm)	0.788
Middling (19/9.5)	40.500
Undersize (<9.5 mm)	21.032

To Bond Wi test work

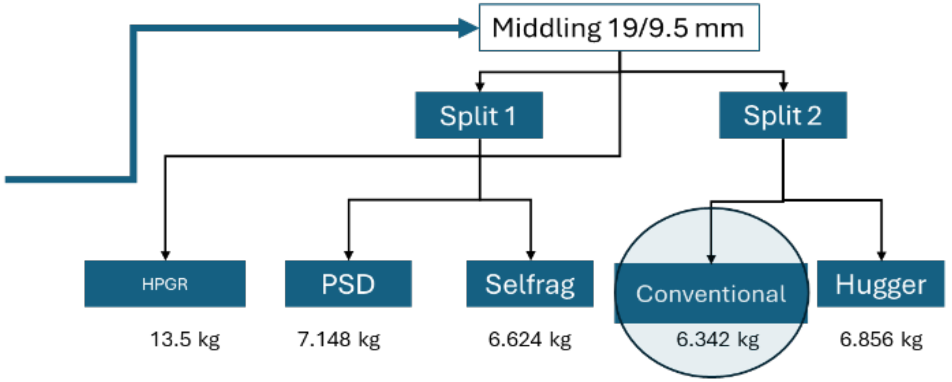

Fig. 4: Division into sub-samples for fragmentation tests

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Conventional comminution: a two-stage crushing and grinding route (jaw crusher + ball mill) as a reference route

Fig. 5: Mini jaw crusher

Fig. 6: Mini jaw crusher product (<3.35mm)

Fig. 7: Ball mill

Fig. 8: Balls for grinding

RESULTS: CLC & HPGR

- Both achieved >20% higher liberation efficiency in comparison with the conventional comminution

- For CLC
  - shows strong potential as a compact, water-free, low-energy technology
  - liberation data for the size fraction < 106 µm showed good liberation for magnetite, and moderate liberation for ilmenite and titanite (fig. 9)
  - more than 20% higher liberation (mass) of magnetite in the size fraction < 106 µm was obtained using solely continuous compression lamella crusher

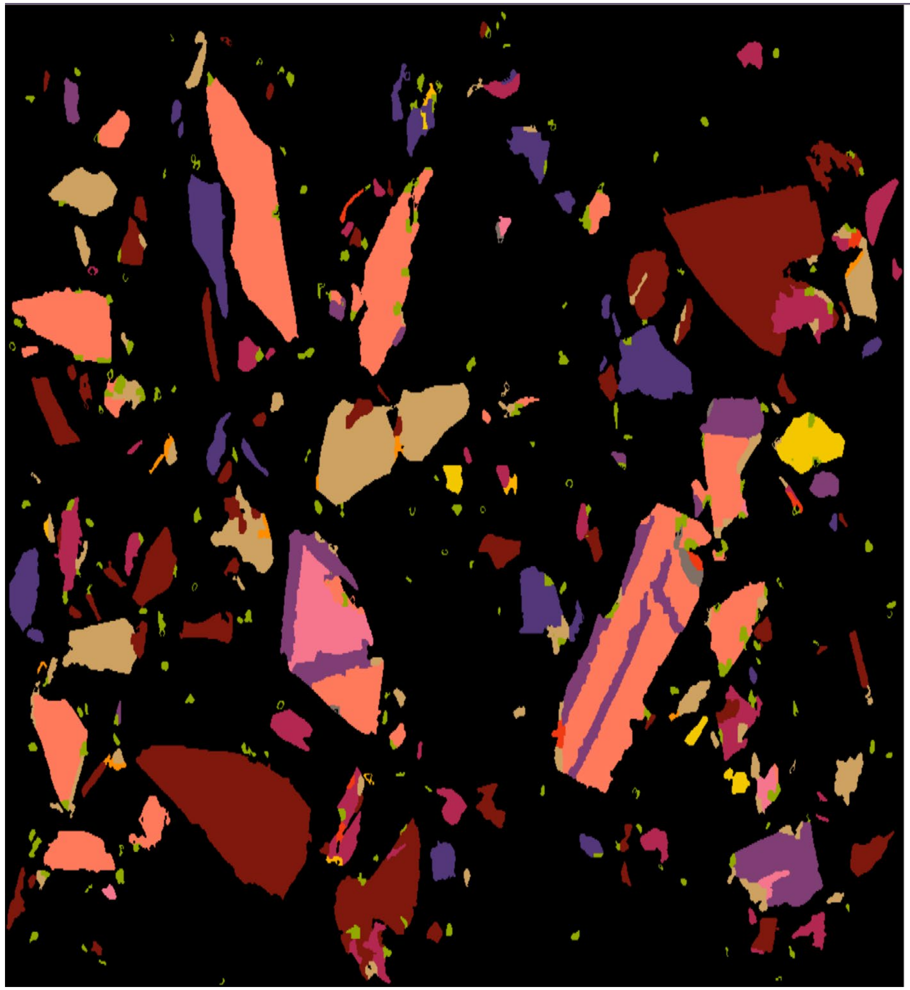

Fig. 9: Electron image of the CLC crushed product (< 106 µm) Magnetite (orange) and ilmenite (purple)

Fig. 10: CLC crusher

- For HPGR
  - shows the best overall performance and highest liberation efficiency across size fractions (<50 µm and 50–100 µm) (fig. 11 & 12)
  - fragmentation to < 50 µm resulted in more than 20% liberation (mass) of magnetite and more than 17% higher liberation of ilmenite (table 1)

Fig. 11: Electron image, 50-100 µm fraction from HPGR
Magnetite (dark blue), Ilmenite (light blue), Titanite (light green)

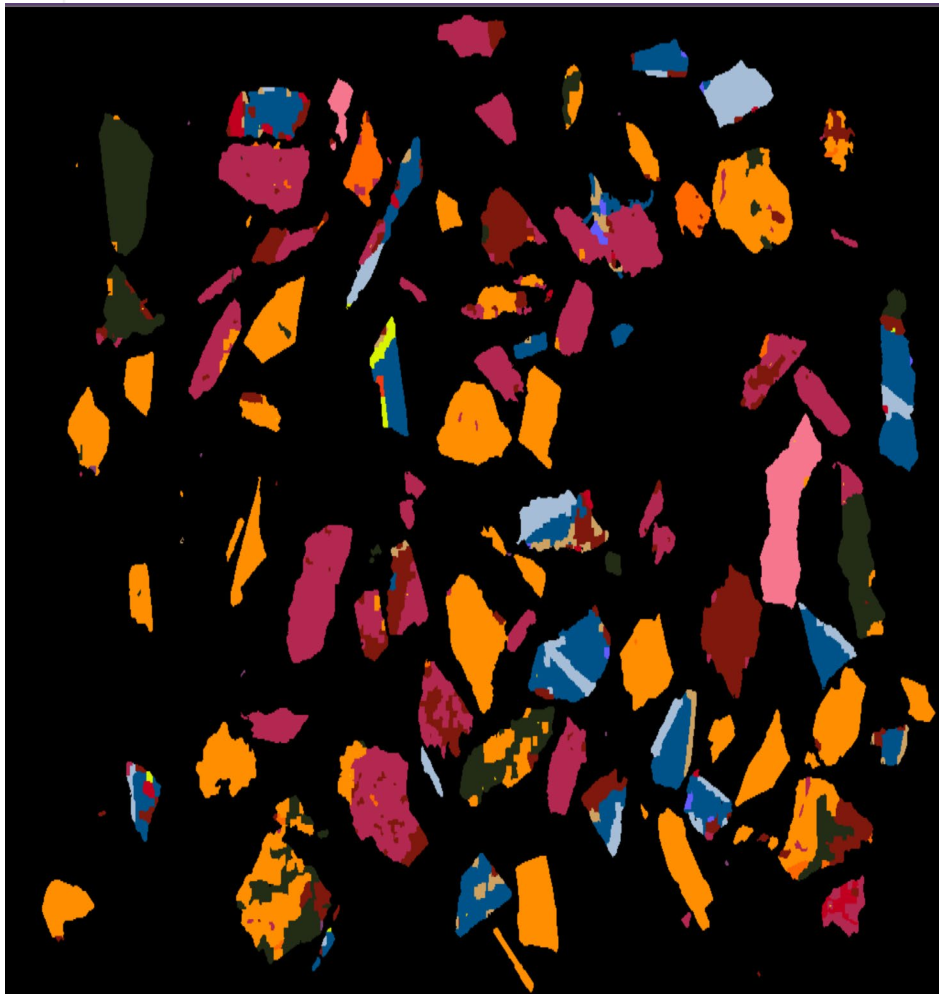

Fig. 12: Electron image, < 50 µm fraction from HPGR
Magnetite (dark blue), Ilmenite (light blue), Titanite (light green)

Table 1: Liberation data of magnetite and ilmenite

Treatment method	Particle size fraction (µm)	Liberation > 90% (mass) of magnetite	Liberation > 90% (area) of magnetite	Liberation > 90% (mass) of ilmenite	Liberation > 90% (area) of ilmenite
Reference test (jaw crusher + ball mill)	< 100	34,37	11,02	40,24	30,73
Fragmentation by CLC	< 106	60,19	26,67	35,40	27,55
Fragmentation by HPGR	50-100	44,04	23,51	29,86	29,19
Fragmentation by HPGR	< 50	69,22	47,10	57,96	39,09

Fig. 13: High pressure grinding rolls

RESULTS: HVPF

- A reference case because it requires water, although very useful
- Three pulse energy levels tested: 150, 500, and 900 pulses
- 900 pulses deliver the best fragmentation and liberation efficiency for magnetite and ilmenite
- Titanite remains less responsive, but liberation improved slightly with higher pulse energy
- HVPF demonstrates strong potential for selective breakage, low-contamination pre-treatment, especially for complex ores

Fig. 14: High-voltage pulse fragmentation device

MINE-TO-MILL INTEGRATION

- Current work integrates selectively blasted Fe-Ti-V ore (mine level) and selective fragmentation (processing level with HPGR and conventional comminution)
- Evaluates full mine-to-mill liberation efficiency and energy footprint from blast to processing
- Early observations show improved grain-boundary breakage even at the initial crushing stage (jaw crusher)
- Supports development of a fully integrated, water-lean flowsheet

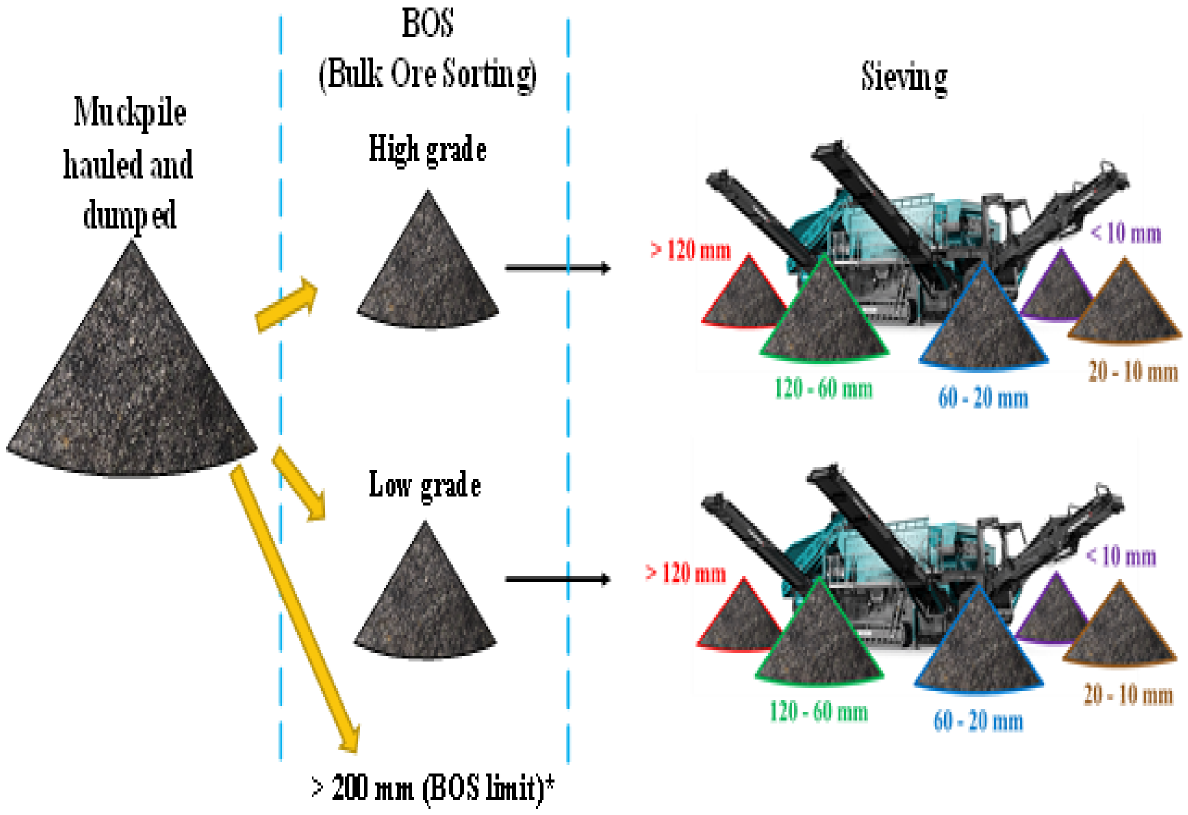

Fig. 15: Mine-to-Mill Blast materials

SCIENTIFIC AND INDUSTRIAL IMPLICATIONS

Scientific:

- Establishes link between selective breakage mechanism and liberation behaviour
- Supports development of energy–liberation models

Industrial:

- Enables water-lean processing pathways for critical Fe-Ti-V resources
- Strong potential for industrial scale-up

Next Steps:

- Combine fragmentation data with magnetic separation tests
- Develop a scalable water-efficient flowsheet for critical raw materials recovery

CONCLUSIONS

Selective fragmentation significantly improves liberation by more than 20% and reduces fines

HVPF provides complementary selective breakage potential

Integration of selective blasting + selective fragmentation enables mine-to-mill optimization

Supports European goals for sustainable processing of critical minerals and their supply

THANK YOU FOR LISTENNG

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