Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 19/10/2026 - **Accepted:** 09/11/2026
Vol: 01.06
DOI: 10.66104/sg9krs33
Pages: 1-38

Ore Competence, Mineral Texture and Feed Variability: Screening Criteria for HPGR Applicability

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Abstract

High-pressure grinding rolls (HPGR) are evaluated as a potential energy-efficient comminution option, but ore competence indices alone cannot establish their suitability across variable geological domains. This critical narrative review organizes a supplied, non-systematically assembled bibliography of 131 records around ore texture, confined-bed response, feed conditioning, representative sampling, circuit boundaries, and industrial transferability. The contribution is a proposed FEL-1 decision framework combining a staged evidence-gated workflow, a qualitative feed-sensitivity matrix, a source-traceability register, and a risk envelope that distinguishes tested from untested feed conditions. Published examples with identifiable methodological detail are differentiated from metadata-only bibliographic context and author-proposed engineering criteria. No new experiments, pooled performance estimates, universal acceptance thresholds, or validated prediction of plant performance are reported. The framework is intended to make outstanding risks and evidence requirements explicit before circuit selection.

Keywords: high-pressure grinding rolls; ore competence; mineral texture; geometallurgical variability; feed characterization; comminution testwork

Highlights

- Ore competence cannot be represented adequately by a single hardness index.
- Texture and particle-bed packing introduce distinct HPGR response mechanisms.
- Representative ore domains and matched circuit boundaries are essential for fair screening.
- A staged, risk-based testwork framework supports FEL-1 route decisions.

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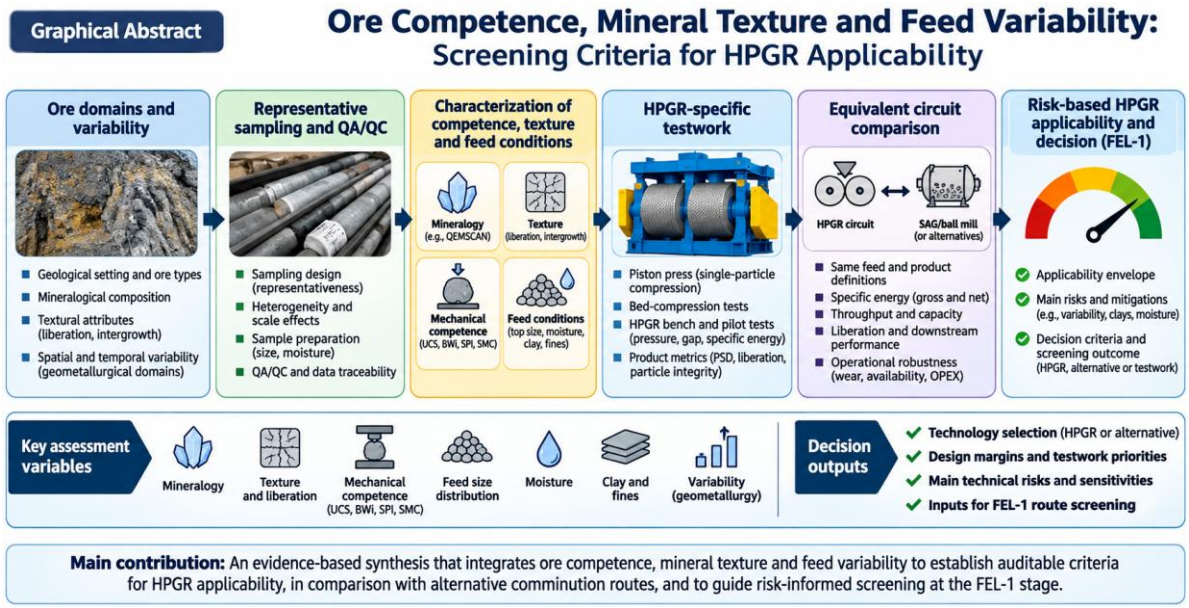
Graphical Abstract



Note. Original schematic illustration produced with AI-assisted image generation; no experimental data are depicted. The author must confirm the final disclosure against journal requirements.

1. Introduction

High-pressure grinding rolls are distinct from conventional single-particle crushing and impact-dominated grinding because a confined particle bed contributes to breakage. A favorable result on a selected ore sample cannot, by itself, establish performance across a deposit whose lithologies, mineral intergrowths, alteration intensity, and fines contents change over time. A scientifically defensible screening exercise therefore asks not only whether material breaks under pressure but whether the production circuit will retain the hypothesized advantage through realistic operating variability (Butcher et al., 2023; Mwanga et al., 2015; Pereira et al., 2023; Rodriguez et al., 2025).

Three engineering questions guide the assessment: what minimum ore-characterization suite suits FEL-1; whether conventional hardness indices alone predict HPGR behavior; and how texture- and feed-dependent uncertainty should affect selection margins. Figure 1 introduces the staged selection process, while Figures 2–4 and Tables 1–3 examine textural

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domains, testwork escalation, circuit boundaries, method limitations, feed sensitivity, and industrial transferability. The comparison is conditional: equivalent feed and product distributions, moisture definitions, net versus gross power boundaries, and downstream liberation must be made explicit before energetic or metallurgical conclusions are transferable.

This paper is a critical narrative synthesis of a bibliography supplied to the author, not a systematic review or an exhaustive search. The manuscript file contains 131 distinct reference-list entries (publication years 2013–2026). The supplied record set includes directly HPGR-related publications, adjacent comminution technologies, geometallurgical sampling, quantitative mineralogy and modelling; inclusion was based on potential relevance to the engineering questions, not on a documented database query. No reproducible historical search string, original assembly date, record-rejection log, or contemporaneous duplicate-removal log was provided. Therefore, a systematic selection cutoff or screening flow diagram cannot be reconstructed. The reference list was inventoried in this revision and an accompanying 131-record documentary register identifies the available bibliographic metadata, preliminary thematic relevance and verification status. It does not claim that all full texts were read. Of the 131 listed records, individual source content and metadata were checked selectively; other records are treated as bibliographic context pending verification. The 131 count describes listed entries, not 131 independently confirmed findings.

The three guiding engineering questions are: E1, which ore-domain and sampling information is necessary for FEL-1; E2, which competence and confined-bed tests can discriminate HPGR response; and E3, how variable feed and whole-circuit outcomes affect an investable decision. Ten thematic questions operationalize them: T1 geological domains (E1); T2 texture and liberation (E1/E2); T3 strength and fracture (E2); T4 conventional versus HPGR-specific tests (E2); T5 top size, fines, moisture and clay (E2/E3); T6 sampling representativeness (E1); T7 variability and domaining (E1/E3); T8 circuit-level comparison and transfer (E3); T9 industrial operating envelope (E3); and T10 integrated testwork priorities

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(E1–E3). The documentary register groups references provisionally by title-based topic; it does not substitute for full-text appraisal. Evidence classes used below are: D (a directly examined HPGR source), C (examined contextual or comparator source), M (metadata-only lead), and P (author-proposed engineering judgment).

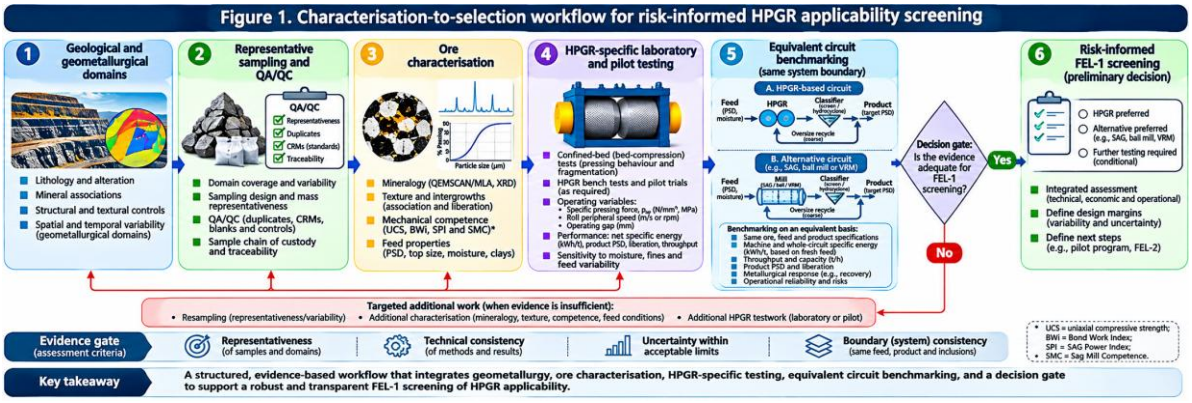

Figure 1. From characterization to a risk-based HPGR selection decision.
Note. Original schematic illustration produced with AI-assisted image generation; no experimental data are depicted. The author must confirm the final disclosure against journal requirements.

The figure depicts a series of decision gates rather than a universal mineralogical classification. It prioritizes traceability: if a pilot result cannot be assigned to a measured ore domain with documented feed and operating conditions, the result should not be used to establish deposit-wide capacity.

2. Ore Types and Geological Variability

Geological variability is not incidental noise in HPGR screening; it is part of the material definition. Lithological contacts, alteration, structural overprinting, and blending modify both particle-strength distributions and the proportion of constituents participating in confined-bed loading. Testwork should stratify these variables before interpreting any average ore response as representative.

Domain classification becomes decision-relevant only when it connects to measured responses and operational exposure. In particular, geology-to-process transfer should specify the fraction of annual throughput represented by each material class and the spatial uncertainty

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of its predicted abundance. A mean work index may be a useful planning descriptor but is insufficient to express the consequences of rare high-competence or sticky domains.

Domain definition must separate geological description from measured comminution response. Comparative testing and three-dimensional characterization offer different forms of information, while process-model assumptions require independent calibration. The cited literature provides methodological points of comparison, not evidence of a transferable HPGR throughput coefficient. Illustrative sources address related methods and boundary conditions (Bravo et al., 2024; Guntoro et al., 2021; Månbro et al., 2025; Pereira et al., 2023). Their individual outcomes must not be inferred from bibliographic titles alone.

3. Mineral Liberation, Texture, and Intergrowth

Mineral texture describes grain size, association, fabric, boundary structure, and the spatial arrangement of mechanically contrasting phases. In HPGR, these characteristics can influence preferential fracture and liberation, but particle-bed confinement introduces interactions that cannot be inferred from isolated mineral hardness.

The critical distinction is between size reduction and valuable-mineral liberation. Finer product does not automatically mean a more economic circuit when regrinding, separation recovery, or dewatering changes. Microcracks observed after compression may indicate damage, yet their frequency and industrial persistence need measurement under equivalent energy and classification conditions.

The conceptual domains in Figure 2 illustrate why an orebody with similar bulk chemistry can contain mechanically different feed populations. The classes are hypothetical; they are used to make test-design assumptions visible rather than to attribute universal response factors.

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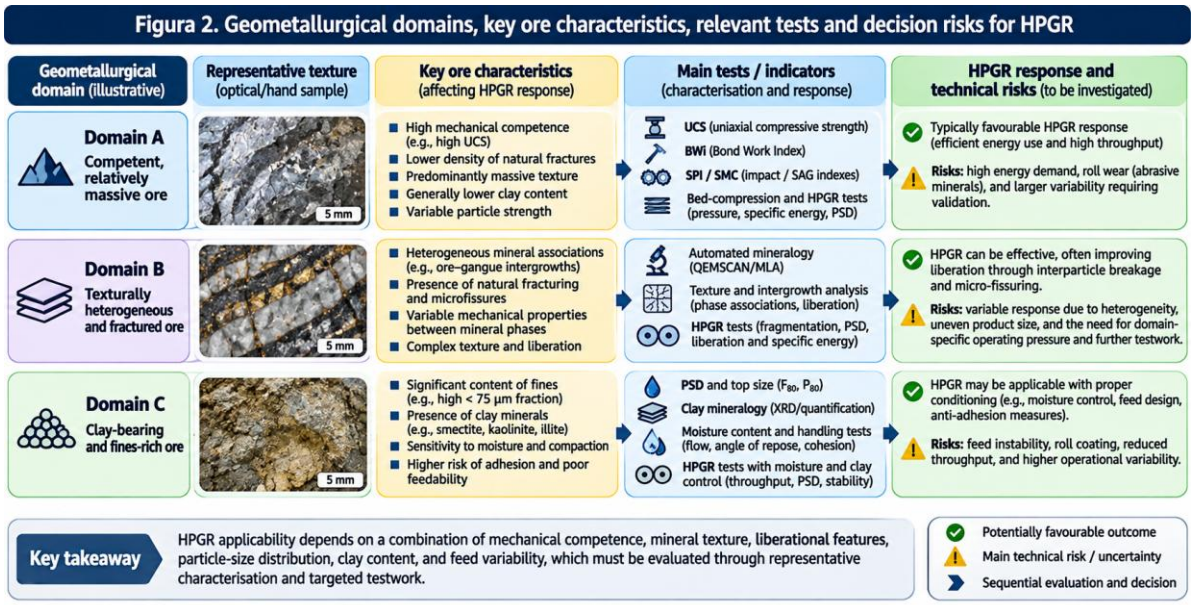

Figure 2. Illustrative geological and textural domains and the uncertainties each can introduce into HPGR selection.
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The critical insight is that both material descriptors and test outcomes should support a classification. Domains defined on appearance alone must be validated against breakage and particle-bed responses.

The mineral-scale literature addresses liberation, texture-sensitive fragmentation, mineral associations, and breakage modelling. These approaches operate at different observation scales and should not be combined as if they measure the same response. For HPGR screening, the important validation is whether texture-dependent changes persist at matched product PSD, measured specific energy, and downstream separation conditions. Illustrative sources address related methods and boundary conditions (Altun & Altun, 2021; Chamlal et al., 2025; Chamlal et al., 2026; Du et al., 2026; Fan et al., 2024; Ferreira & Lima, 2024; Lieberwirth et al., 2025; Lois-Morales et al., 2026; Moutinho et al., 2026; Pereira, 2026b; Pereira, 2026d; Rocha et al., 2025; Xu et al., 2025; Zhang et al., 2024b). Their individual outcomes must not be inferred from bibliographic titles alone.

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4. Compressive Strength, Abrasion, and Fracture Response

Compressive strength, tensile strength, abrasion resistance, and fracture-energy distributions characterize overlapping but non-identical aspects of mineral breakage. Uniaxial tests on intact specimens do not recreate a heterogeneous compressed particle bed, and single-particle methods can exaggerate weak-grain pathways relative to industrial mixed-feed conditions.

A defensible test plan reports specimen preparation, loading rates, particle size, replicate counts, and the spread—not merely the central value—of failure responses. Uncertainty in strength estimation should be propagated into throughput and specific-energy predictions rather than silently absorbed into design contingency.

Conventional rock-strength, abrasion, and drop-weight measurements test different stress modes from confined-bed loading. Their principal value is to characterize variability and formulate testable HPGR hypotheses; extrapolation to industrial throughput requires calibration with compression or circuit observations. Illustrative sources address related methods and boundary conditions (Adewuyi et al., 2024; Altun et al., 2026; Bhuiyan et al., 2022; Camalan & Yahyaei, 2024; Das & Abuel-Naga, 2024; de Almeida et al., 2024; Ghadernejad et al., 2026; Mesa et al., 2025; Nghipulile et al., 2024; Nghipulile et al., 2022; Petit et al., 2025; Santosh et al., 2022; Yang et al., 2025; Yildirim et al., 2025). Their individual outcomes must not be inferred from bibliographic titles alone.

5. Bond Work Index, SPI, SMC, and HPGR-Specific Tests

Bond work index, SAG power index, SMC-type characterization, drop-weight response, and HPGR-specific compression tests were developed for different loading regimes and product definitions. Do not treat their numerical values as interchangeable ore-competence scales. Correlation for a given deposit may be useful, but its calibration and external validation must be documented.

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Small-sample methods are attractive during FEL-1, where material quantity is limited. However, their predictive value depends on initial feed distribution, packing, moisture, confinement, pressing force, scale-up, and whether the target is machine throughput, specific energy, or downstream grindability. A modest correlation among indices is not a validated industrial HPGR capacity model.

A checkable example is Thivierge et al. (2022), who unified gap, mass-flow, power, and centre/edge product-size models and calibrated them using 18 pilot-scale datasets under constant feed PSD and moisture within each dataset. Their reported predictive scope is confined to calibration conditions; it is not evidence that Bond, SPI, or SMC indices independently predict HPGR industrial throughput (evidence class D, source abstract examined).

Table 1 classifies the role of characterization methods. Its categories are decision-oriented, not a claim of universal quantitative correlations or identical standard test protocols.

Table 1. Decision value and limitations of ore characterization tests

Method	Primary decision value	Key limitation
Quantitative mineralogy / XCT	Texture, associations, phase distribution	Sampling scale and segmentation bias
UCS / tensile / abrasion	Intrinsic strength and wear tendencies	Not confined-bed response
Bond / SPI / drop-weight	Grinding/impact competence indices	Different loading regimes and circuit calibration
Piston press/bed compression	HPGR-relevant packing and pressure response	Scale-up, edge geometry, moisture
Pilot HPGR + circuit survey	Throughput, energy, PSD and operational stability	Cost and limited variability coverage

Note. Author-proposed classification (P). The method roles reflect distinct measurement targets and are not calibrated rankings; see the 131-record documentary register for source-status details.

The methods are complementary rather than interchangeable. A practical program should favor the least expensive test that closes a material decision gap, while recognizing that only a calibrated bed-compression or HPGR trial can directly test the confined-bed hypothesis.

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Characterization methods differ in sample support, loading mechanism, and the response they estimate. Work-index testing, process optimisation, and piston-press scaling can inform screening, but none should be used as a substitute for a calibrated closed-circuit HPGR prediction. Illustrative sources address related methods and boundary conditions (Ashrafpour, 2026; Kumar et al., 2023; Li et al., 2026; Ma et al., 2022b; Ma et al., 2022a; Pamparana et al., 2022; Pereira, 2026c). Their individual outcomes must not be inferred from bibliographic titles alone.

6. Feed Top Size, Moisture, Clay, and Fines

Feed top size, fine-particle content, moisture, and clay mineralogy control the packed bed before particles fracture. A shift in any one variable can change nip behavior, air voids, bed density, edge effects, material flow, and the balance between interparticle stressing and agglomeration.

These influences can be non-monotonic and deposit-specific. A simple specification such as maximum moisture is therefore not a universal acceptance rule: it must be related to actual clay species, conditioning history, feed segregation, and recycle load. For each planned scenario, tests should preserve as-received granulometry and separately evaluate deliberately reconstituted blends.

Table 2 shows how feed variables can create risks that should be tested experimentally rather than replaced by a single universal acceptance threshold.

Table 2. Qualitative feed-sensitivity screening matrix

Feed dimension	Potential mechanism	Recommended evidence
Top size / oversize	Nipping and heterogeneous loading	PSD and oversize simulations/trials
Fines and packing	Bulk density, bed contacts, fines generation	Graded blends; bed-compression curves
Moisture/clay	Cohesion, handling, adhesion, possible choke	Clay mineralogy; moisture-conditioned tests
Segregation	Feed-side and axial asymmetry	Feed audits, edge/centre samples

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Feed dimension	Potential mechanism	Recommended evidence
Recycled product	Changed packing and effective residence	Closed-circuit/piston-press iterations

Note. Author-proposed hypotheses (P), not experimentally validated operating limits. Each row requires deposit-specific confirmation; literature titles alone are not used to establish causality.

The matrix treats moisture–clay interactions as a separate experimental dimension. Observations from dry bench specimens must not be extended to wet plant feeds without reconditioning and verification.

Feed-size distribution, fines, clay mineralogy, and moisture interact through packing, cohesion, and handling behavior. Therefore, evaluate evidence from differently conditioned samples with explicit feed PSD, moisture conditioning, recycle ratio, and scale before inferring a process advantage. Illustrative sources address related methods and boundary conditions (Aminalroaya & Pourghahramani, 2022a; Aminalroaya & Pourghahramani, 2022b; Campos et al., 2020; Izadi-Yazdan Abadi et al., 2025b; Lieberwirth & Kühnel, 2021; Nghipulile et al., 2023; Őze et al., 2023; Pamparana et al., 2024; Saramak & Leśniak, 2024; Wang et al., 2025; Wang et al., 2026; Zhang et al., 2024a). Their individual outcomes must not be inferred from bibliographic titles alone.

7. Sampling Design and Representativeness

Without representative sampling, high-quality breakage apparatus can produce precisely measured but irrelevant results. Sample support, particle-size segregation during collection, selective loss of fines, and compositing over lithological boundaries may obscure the distribution of competence values needed for design.

A fit-for-purpose sampling protocol should define geological domains, minimum increments, sample masses, chain of custody, processing sequence, replicate splitting, and checks for moisture and size redistribution. The sampling objective differs between finding an average response and identifying low-frequency operational risks.

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A representative test campaign should retain paired geological metadata and physical sample attributes. Sampling is not merely sample collection; it is the procedure that makes uncertainty about future plant feed measurable.

Geometallurgical sampling and ore-domain clustering must preserve geological context and account for scale and spatial dependence. Such methods help select test samples, but their predictive value for HPGR performance must be established from measured responses. Illustrative sources address related methods and boundary conditions (Adeli et al., 2021; Dominy & Glass, 2025; Minnitt & Minkkinen, 2026; Niquini et al., 2025; Silva et al., 2025a; Silva et al., 2025b). Their individual outcomes must not be inferred from bibliographic titles alone.

8. Variability Testwork and Geometallurgical Domaining

Geometallurgical domaining should connect geological evidence with process-response predictors and uncertainty. A statistically sharp cluster obtained from a large set of correlated descriptors is not automatically a useful plant domain if the resulting classes do not predict material behavior or occur at actionable mining scales.

Cross-validation should be spatially explicit and, where possible, performed on deposits or mining phases not used for model calibration. For HPGR, domains that separate texture but not packing, moisture, or fragmentation may need to be split or recombined according to the process decisions under investigation.

Figure 3 proposes a staged sequence that escalates from cheap descriptors to expensive engineering evidence. Escalation depends on the risk that a screening error would impose on the subsequent investment decision.

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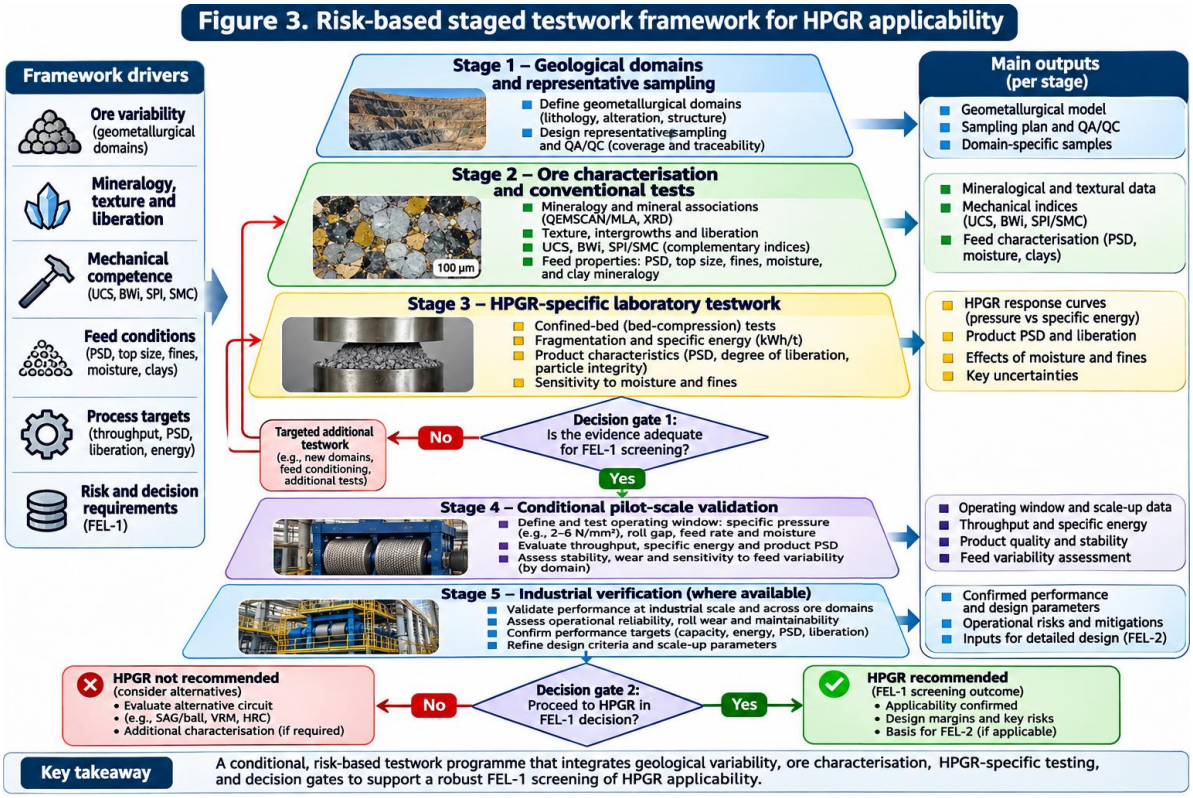

Figure 3. Escalating testwork from geological context to industrial validation.
Note. Original schematic illustration produced with AI-assisted image generation; no experimental data are depicted. The author must confirm the final disclosure against journal requirements.

The route should be revised when tests reveal a new domain, bimodal fracture population, or transport/handling constraint. This approach is more transparent than deriving a fixed confidence margin from a small convenience sample.

Predictive domaining, breakage testing, and process optimization provide complementary inputs to staged decisions. Domain boundaries should be challenged with independent spatial validation and samples representing operational extremes, not merely by statistical separation. Illustrative sources address related methods and boundary conditions (Batista et al., 2026; Freire da Silva et al., 2026; Kabemba et al., 2025; Merrill-Cifuentes et al., 2023; Moraga et al., 2022; Quelopana et al., 2023; Rodovalho et al., 2025; Roslin, 2026; Tiu

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et al., 2023; Viana et al., 2025). Their individual outcomes must not be inferred from bibliographic titles alone.

9. Selection Metrics and Transferability Among Deposits

HPGR route selection is a multi-criterion comparison, not a single-value energy ranking. Matching the physical feed and target product is indispensable; system boundaries should also capture classification, circulating load, downtime, wear, downstream liberation, water management, and uncertainty.

Transferability from one orebody to another is conditional on congruent microstructural and operational envelopes. Results from silicate weathering, manufactured sand, spodumene, iron ore, or flotation pretreatment can suggest mechanisms, but application to a different ore class requires separate validation.

Figure 4 formalizes the boundary problem. Comparing a reported HPGR motor specific energy with the gross electrical demand of a milling circuit or the net mill power of another route is not sufficient.

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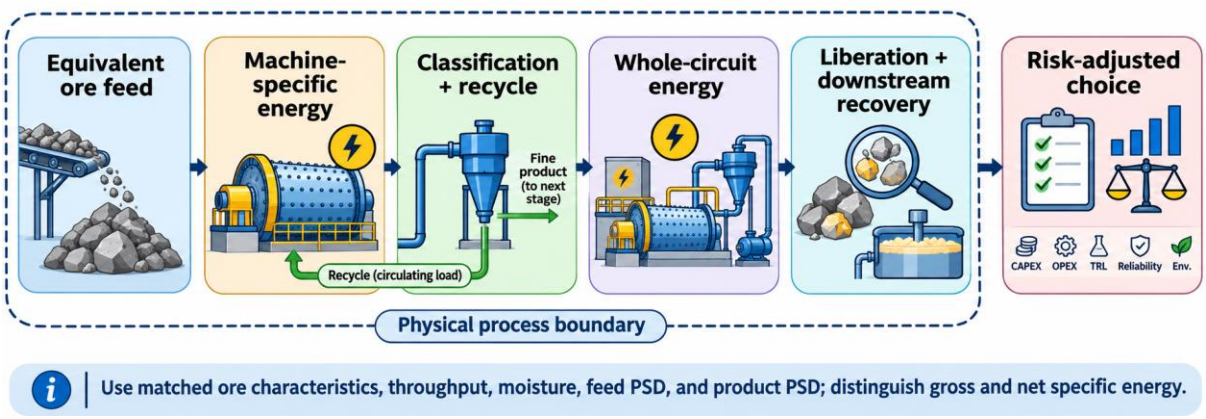

Figure 4. Physical process boundaries, circuit-energy accounting, and risk-adjusted selection criteria for comparing comminution routes.
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The appropriate outcome is a circuit-level trade-off that makes energy, achievable PSD, valuable-mineral liberation, maintenance, availability, and sensitivity to feed variability visible at the same decision boundary.

Published comminution comparisons address different ore types, circuit configurations, energy boundaries, and separation endpoints. They can identify variables worth testing, but directly ranking HPGR against alternative routes requires a common ore feed, matched final product PSD, and consistent, circuit-specific energy accounting. Illustrative sources address related methods and boundary conditions (Akhmetov et al., 2025; Almeida et al., 2023; Chen et al., 2023; Drechsler et al., 2026; Göktaş et al., 2023; Heinicke et al., 2022; Koh et al., 2021; Marzoughi et al., 2026; Mokgomola et al., 2025; Nagata et al., 2020; Ozcan et al., 2015; Penagos et al., 2025; Rocha et al., 2026; Santosh et al., 2023; Saramak & Saramak, 2024; Tang et al., 2020; Thatipamula & Devasahayam, 2025; Tian et al., 2024; Wei et al., 2026; Wu et al., 2025; Yu et al., 2024; Yu et al., 2026; Zhang et al., 2024c). Their individual outcomes must not be inferred from bibliographic titles alone.

A complementary example at a different scale is Sesemann et al. (2013), who described a laboratory approach to estimating HPGR roll wear. This addresses a wear-testing question,

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not an ore-independent energy saving or plant availability estimate (evidence class D, publisher abstract checked). Pereira et al. (2023) discuss mineral-particle texture and modeling in mineral processing and provide a methodological analogy, rather than a direct HPGR plant comparison (evidence class C, journal full text accessible).

10. Risk-Based Industrial Applicability Envelopes

Industrial applicability depends on whether a candidate circuit can tolerate the realistic envelope of ore properties and operating constraints. Nominal force, gap, and roll-speed settings describe the machine, but uneven feeding, material segregation, evolving wear profiles, and recycle dynamics can change realized performance.

Mechanistic and DEM-informed models can support sensitivity analysis, provided they disclose their assumptions, calibration windows, and numerical uncertainty. Published plant observations should be preferred for practical risk calibration; however, a single trial at one material state does not establish all-season reliability.

Table 3 summarizes how scale-up risks can be attached to evidence needs without claiming universal correction factors. A pilot program that samples only convenient feed cannot close geological risk, regardless of how sophisticated the machine instrumentation is.

Table 3. Geometallurgical variability and industrial scale-up risks

Risk	Screening indicator	Qualification step
Competence heterogeneity	Spread across domain hardness indices	Stratified tests/scenario simulation
Segregation/edge effect	Axial PSD, wear, feeding differences	Pilot/plant roll-width surveys
Moisture/clay changes	Conditional feed cohesion and packing	Wet/dry conditioning program
Energy accounting	Mixed gross/net reporting boundaries	Matched circuit mass-energy balance
Liberation transfer	Product size vs separation discrepancy	Mineralogy + downstream pilot response

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Note. Original conceptual synthesis (P); the listed indicators are qualification targets, not independently validated industrial correction factors.

A risk envelope should explicitly distinguish feasible operation, expected operation, and an untested region. Drawing a narrower range does not eliminate uncertainty; it reduces it by exposing the process to representative materials and documented operating tests.

HPGR applicability depends on axial feed distribution, edge effects, rolls and liner wear, control strategy, and the capacity of the coupled circuit. Models and case studies should be distinguished from industrial validation: their practical transfer depends on the investigated machine geometry, material envelope, calibration data, and runtime. Illustrative sources address related methods and boundary conditions (Anticoi et al., 2019; Cleary & Sinnott, 2021; Costa et al., 2025; Guo et al., 2025; Guo et al., 2024; Izadi-Yazdan Abadi et al., 2025a; Johansson & Evertsson, 2019; Li et al., 2023; Massinaei & Javanshiri, 2026; Rodriguez et al., 2022a; Rodriguez et al., 2021; Rodriguez et al., 2022b; Rodriguez et al., 2024; Rodriguez et al., 2025; Rodriguez et al., 2023; Seerig et al., 2024; Tahaei et al., 2025; Thivierge et al., 2020; Thivierge et al., 2022; Tojaga et al., 2025; Wei et al., 2025; Yang et al., 2024; Zhang et al., 2025; Zhang et al., 2022; Zhang et al., 2026; Zheng et al., 2025; Zou et al., 2023). Their individual outcomes must not be inferred from bibliographic titles alone.

11. Critical Synthesis and Testwork Priorities

The synthesis separates direct HPGR observations from methodological parallels and technology comparators. A recurring challenge is to preserve the same measurement boundaries from laboratory specimen through ore domain, feed blend, and operating circuit. Apparent contradictions among studies often become interpretable once the feed definition, specific-energy basis, testing scale, and liberation endpoint are made explicit.

For FEL-1, the goal is an auditable decision under uncertainty rather than a premature final decision. The program consists of geological and sampling review, representative size

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characterization, quantitative mineralogy and texture, selected conventional hardness testing, and at least one HPGR-relevant comminution program on contrasting ore domains.

Table 4. Evidence-gated FEL-1 workflow and explicit qualification conditions.

Stage/decision	Minimum documented evidence	Qualitative gate and residual uncertainty
1. Define exposure	Ore-domain map, mining sequence, sample provenance and sample mass	Advance when relevant domains and extreme conditions are represented; otherwise expand sampling; unknown exposure → undetermined.
2. Test descriptors	Size/moisture/texture assays, repeatability, selected conventional indices.	Advance when domain variability is bounded for targeted comparison; discordance → segregate domains and repeat.
3. Test confined bed	Conditioned bed-compression or HPGR pilot results for contrasting domains, specific energy, PSD, wear/handling notes	Advance only if data resolve the route-critical confined-bed question; otherwise additional testing or undetermined.
4. Compare circuits	Common ore/feed basis, final PSD, gross/net energy boundaries, classification, separation or regrinding response	Advance to FEL-1 shortlist only if comparisons share declared functional and energy boundaries.
5. Assign decision status	Evidence ledger, residual risks, assigned owners and project-specific acceptance criteria	Feasible = tested under stated conditions; expected = justified but not yet demonstrated; untested = no empirical coverage. No absence-of-evidence approval.

Document the gate outcome as advance, extend testing, or undetermined, and record the decision owner, date, ore domains covered, disqualifying conditions, and remaining uncertainty. A missing adverse observation is not affirmative proof of suitability. For illustration only, a hypothetical competent dry domain may advance after paired bed-compression and matched PSD/energy trials. In contrast, an untested wet, clay-rich domain remains outside the feasible envelope until conditioned testing is completed. No performance values or validation are implied.

A screening program should join sample representativeness and low-material-consumption breakage measurements to focused pilot and industrial evidence. The sources

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cited below motivate complementary test choices but do not constitute a validated universal HPGR selection rule. Illustrative sources address related methods and boundary conditions (Baawuah et al., 2020; Bueno et al., 2023; Bueno et al., 2024; Bueno et al., 2021; Butcher et al., 2023; Campos et al., 2021; Gu et al., 2025b; Mwanga et al., 2015; Nikolić et al., 2025; Pereira, 2026a; Pereira, 2026e; Samur et al., 2026; Sesemann et al., 2013). Their individual outcomes must not be inferred from bibliographic titles alone.

An illustrative comparison—not a documented contradiction between two identified studies—would arise when a test reports low machine-specific energy but a different feed condition exhibits poor bed formation or downstream liberation. These are different response variables and may represent a circuit trade-off rather than mutually inconsistent evidence. To claim a literature disagreement, both sources would need to verify the same material, scale, conditioning, energy boundary, and outcome. Accordingly, this review does not assert a resolved cross-study conflict; it proposes an evidence register for ore domain, sample support, test scale, feed PSD, moisture, operating pressure, duration, power boundary, product PSD, liberation, and uncertainty.

This paper's distinctive contribution is not a new breakage law or a reported HPGR performance gain. It integrates (i) geological representativeness, (ii) texture and confined-bed mechanics, (iii) comparable circuit energy and liberation boundaries, and (iv) explicit evidence status into a single sequential FEL-1 decision record. The relationships derive partly from cited methods and partly from proposed qualification judgments; the specific gates and risk classification are author-developed instruments requiring project-specific testing.

Research priorities are paired with practical decisions: quantify domain strength distributions; validate affordable confined-bed tests against pilot HPGR; measure clay/moisture–packing interactions; compare liberation at matched circuit product size; and design trials that report repeatability and axial non-uniformity. These recommendations are a proposed framework, not an independently validated predictive model.

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12. Conclusion

Ore competence and HPGR applicability should be assessed as joint properties of material, sampling design, and operating system rather than as a single universal hardness threshold. Mineralogical texture, fracture behavior, particle-size distribution, bed packing, moisture, and geometallurgical variability interact with circuit design and can alter the apparent advantages of confined-bed compression. Conventional indices provide complementary screening information, whereas domain-calibrated bed-compression, pilot, and industrial observations offer stronger direct tests of HPGR response. For FEL-1, the recommended approach is a staged evidence program with explicit sample representativeness, competing-circuit boundaries, qualitative risk envelopes, and uncertainty reporting. The resulting framework supports transparent route selection while acknowledging that deposit-independent numerical acceptance limits and fully reliable laboratory-to-plant transfer functions remain unestablished.

Declarations

Funding

This review received no specific external funding.

Conflict of Interest

The author declares no conflict of interest.

Data Availability

No new experimental datasets were generated. All quantitative values discussed in the review are traceable to the cited literature.

Author Contributions

The author performed conceptualization, critical analysis, literature synthesis, visualization, and manuscript preparation.

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