Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Laos and Vietnam in the Emerging Rare Earth Supply Chain: Ion-Adsorption Frontiers, Resource-to-Industrialization Gaps, Processing Constraints, and Strategic Outlook (2020–2026)

Antonio Clareti Pereira, PhD
PhD in Chemical Engineering
University of São Paulo (USP)
Belo Horizonte, Minas Gerais, Brazil
E-mail: claretipereira@gmail.com
ORCID: https://orcid.org/0000-0001-8115-4279

Abstract
Laos and Vietnam occupy distinct positions in emerging rare-earth element (REE) supply networks. Laos is becoming a frontier for regolith-hosted ion-adsorption deposits with potential heavy-REE relevance, while Vietnam possesses varied hard-rock and secondary geological occurrences but has yet to translate its mineral endowment into sustained, integrated industrial production. This critical review compares geological confidence, project reporting, mineralogical variability, recovery chemistry, separation capabilities, cross-border trade dependence, environmental burdens, and development constraints using a source-quality framework that distinguishes resources, reserves, soluble REE inventories, pilot production, nameplate capacity, and verified output. The synthesis demonstrates that exchangeability, hydrodynamic accessibility, and reagent recirculation govern much of the feasibility of ionic-clay recovery, whereas Vietnamese fluorocarbonate- and phosphate-bearing ores demand mineralogical discrimination, selective concentration, decomposition, and radionuclide control. A comparative value-chain-readiness framework is proposed without assigning unsupported national maturity scores. The central finding is that diversification of mined feedstocks alone cannot ensure diversification of separated oxides, metals, alloys, or magnets. Sustainable participation requires transparent project-level evidence, representative metallurgical testing, demonstrable environmental control, and commercially qualified downstream products.

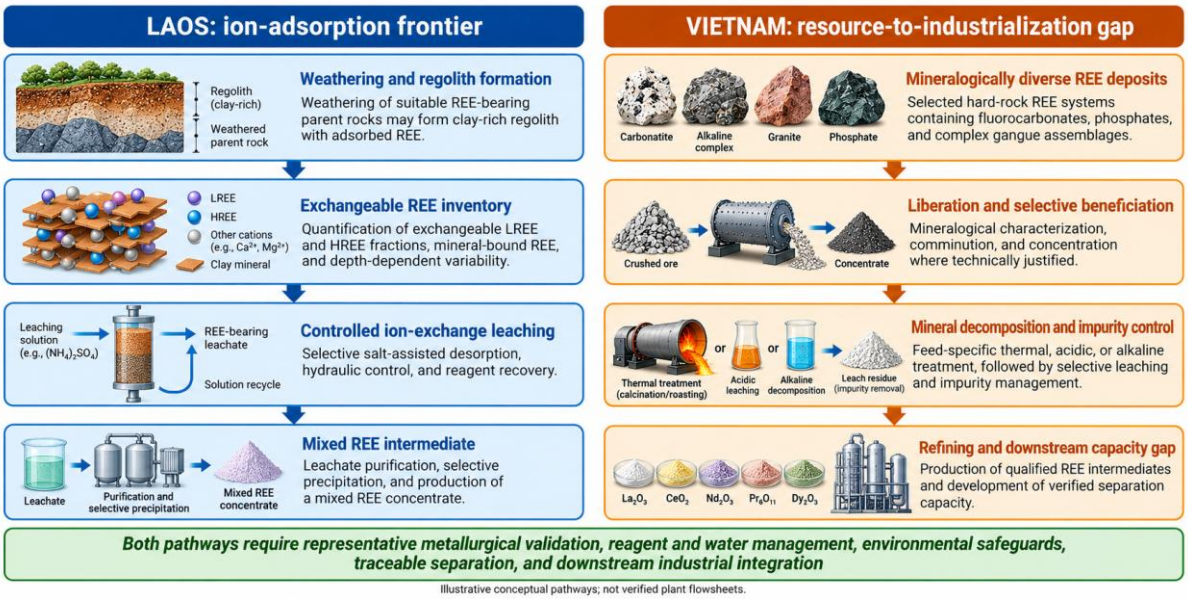
Keywords: rare earth elements; Laos; Vietnam; ion-adsorption clays; heavy rare earth elements; supply-chain diversification

Highlights
- Laos and Vietnam represent different REE deposit and industrial-development models.
- Soluble REO, total resources, reserves, and commercial outputs must remain distinct.
- Processing selectivity and environmental safeguards depend strongly on mineralogy.
- True supply diversification requires independently validated refining and value capture.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Graphical abstract



1. Introduction: Laos and Vietnam in the Changing Asian REE Supply Geography

Rare earth elements are indispensable to advanced magnets, selected electronics, catalysts, and energy systems. Their strategic criticality depends not only on ore abundance but also on the uneven geographic distribution of chemical separation, alloying, and magnet manufacturing. The concentration of these downstream operations creates bottlenecks that new mines cannot resolve on their own (Balaram, 2023; Chen et al., 2024; International Energy Agency, 2025; Depraiter et al., 2025).

The two neighboring Southeast Asian jurisdictions represent a scientifically useful contrast. Laos is associated with weathered granitoid profiles and an emerging evidence base for adsorption-hosted HREE occurrence, whereas Vietnam hosts geologically diverse fluorocarbonates, phosphates, and other REE assemblages. Accordingly, metallurgical routes and their environmental burdens are not interchangeable (Bui et al., 2025; Cardenas-Vera et al., 2022; Xie et al., 2026; Ye et al., 2025).

The article first defines its source-confidence criteria (Table 1), then contrasts geological, resource, and project evidence (Tables 2 and 3). It compares process pathways

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

(Table 4) and environmental and value-chain readiness conditions (Table 5). Figure 1 visualizes the difference between regolith and hard-rock mineralization, and Figure 2 compares process routes. Figure 3 distinguishes between diversification of mined feedstocks and diversification of high-value transformation, while Figure 4 illustrates the proposed diagnostic readiness architecture. The central questions are whether both countries can generate reliable, environmentally defensible supply and whether new regional extraction also creates alternatives to established processing centers (Xu et al., 2024; Woods, 2025; Zhiltsov & Hoang, 2025).

2. Review Methodology and Evidence-Confidence Framework

2.1. Search scope and evidence screening

This study is a critical narrative comparative review, not a systematic review or quantitative meta-analysis. Its evidence window covers January 2020–October 2026. The supplied starting bibliography comprised 135 records, integrating country-specific studies, process and environmental analogs, and institutional market and reserve reports. The original search concepts included Laos, Vietnam, Dong Pao, Meng Khun/Mengkham, Houaphanh, Nam Xe, Yen Phu, ion-adsorption, exchangeable or soluble REO, flotation, hydrometallurgy, reserves, operating production, separation, and trade. The historical search log, queried databases, search strings, language restrictions, citation-chaining log, and last original retrieval date were not supplied; therefore, they cannot be reconstructed as a reproducible search protocol. A targeted supplementary check of the IEA 2026 outlook and institutional reserve publications was conducted on 19 October 2026. Source-specific relevance and bibliographic metadata must be checked against the underlying works before certification of a complete reference audit. Accordingly, the 135 supplied records are described as a documentary corpus, not as 135 independently validated source-claim pairs.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

2.2. Evidence categories and reporting harmonization

Country-level reserve estimates, project resource statements, corporate announcements, peer-reviewed experiments, and customs statistics support different propositions and must be evaluated against the claim actually made. Total rare-earth oxides (TREO) denotes the sum of REE concentrations expressed as oxide equivalents for the specified set of elements and analytical basis. Soluble/exchangeable rare-earth oxides (SREO) denotes an operationally extractable oxide-equivalent inventory, not a universally defined mineral reserve: its analytical leachant, pH, contact time, liquid-to-solid ratio, extraction protocol, dry-mass basis, and analyzed element suite must be specified for comparability. The element-specific exchangeable fraction is f_exchange,i = m_i,exchangeable / m_i,total. JORC, NI 43-101, CRIRSCO-aligned disclosures, national classification systems, and USGS country estimates must be identified by their distinct reporting basis and must not be pooled. Similarly, a license, test campaign, constructed facility, design capacity, commercial shipment, and verified continuous output are different milestones (U.S. Geological Survey, 2024, 2025, 2026). Table 1 organizes source types by claim-appropriate evidence, without a universal rank ordering.

Table 1. Claim-specific evidence classes for REE geological, operational, and market assertions

Evidence class	Evidence class	Appropriate inference
A	Official or competent-person audited data	Edition-specific, qualified resources, reserves, or output
B	Independent technical report with transparent methods	Project-level estimate, with declared limitations
C	Peer-reviewed geological or metallurgical work	Sample-specific or mechanistic evidence
D	Customs proxies or indirect company disclosures	Indicative flow; conversion and classification needed
E	Unverified announcement or media assertion	Lead for verification, not established production

Note. Original author-developed classification; classes are descriptive rather than ordinal. Confidence depends on the proposition, traceability, analytical method, reporting scope, and date. Peer-reviewed process measurements can be stronger than official national estimates for mechanistic claims, whereas verified project reports may be more relevant to reserves.

The evidentiary strength of each class is claim-dependent. Analog studies can demonstrate reaction or flow mechanisms but cannot establish a Lao or Vietnamese reserve,

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

national production figure, or site-specific environmental performance. Conversely, an official estimate may be relevant to national reported reserves without independently establishing the technical feasibility or economics of a named deposit.

3. Geological Endowment and Deposit Types

3.1. Laos: ion-adsorption regolith and weathering control

The weathering of rare-earth-bearing granitoids can redistribute REE through dissolution, migration, sorption, and partial immobilization in secondary phases. Parent-rock enrichment alone does not establish the accessible HREE inventory, because mineral retention and selective adsorption vary by horizon, clay type, and weathering history (Russo et al., 2025; Liu et al., 2022; Xie et al., 2026). Northern Lao occurrences warrant horizon-specific measurements of Nd, Pr, Dy, Tb, Y, ionic exchangeability, and mineral-hosted fractions.

3.2. Vietnam: carbonatite-related, metasomatic, and other REE hosts

Dong Pao is an illustrative multiphase system in which bastnäsite, parisite, synchysite, and related minerals can coexist with carbonate and gangue phases. The result is not a single mineral-processing feed, but a collection of domains that may have different liberation, flotation, reagent-consumption, and downstream behavior (Bui et al., 2025; Sun et al., 2023). Nam Xe and Yen Phu further extend the mineralogical spectrum, including preconcentration challenges and locally relevant radionuclides (Cardenas-Vera et al., 2022; Hung et al., 2022). Figure 1 depicts the conceptual geological contrast.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

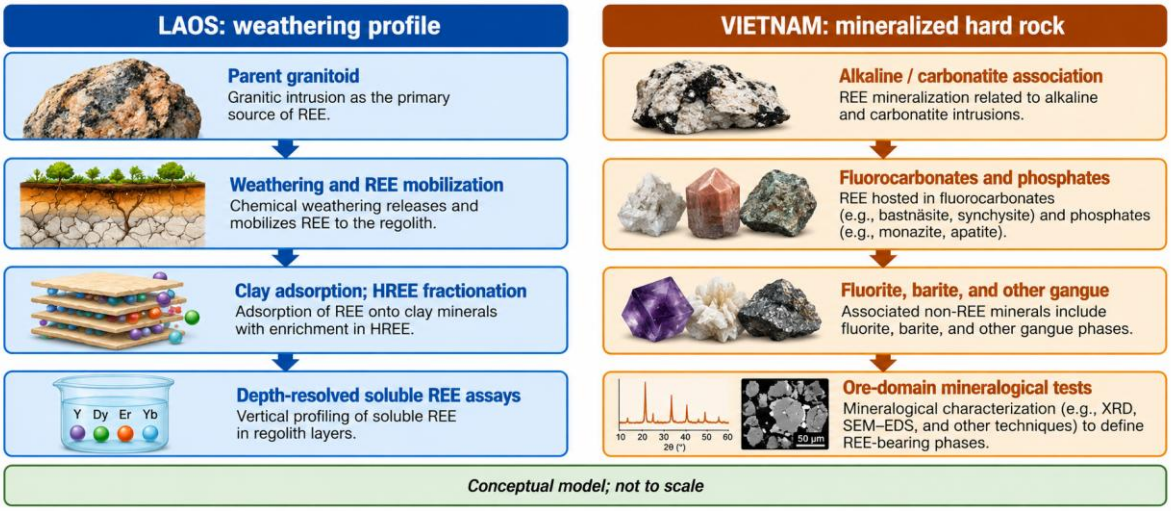


Figure 1. Conceptual contrast between Laotian weathered ion-adsorption profiles and Vietnamese multiphase hard-rock REE systems.

Note. Original conceptual figure prepared for this review, informed by the cited literature; no previously published artwork was reproduced. An "Adapted from" credit is therefore not applicable. Figure 1 emphasizes contrasting requirements for geological sampling. Laos must demonstrate depth-resolved exchangeability and fluid access; Vietnam must document mineral assemblages, liberation, textures, gangue associations, and deposit-domain variability. The schematic is not a geological map or quantitative cross section.

Geological analogs in the expanded evidence base illuminate weathering pathways, spatially heterogeneous enrichment, and deposit-specific mineral hosts. They do not independently establish the tonnage, compositional vector, or reserve category of any Lao or Vietnamese project (Balaram, 2023; Bui et al., 2025; Chen et al., 2024; Jiang et al., 2025; Liu et al., 2022).

Across direct country studies and external geological analogs, differences in parent-rock chemistry, weathering horizons, clay assemblages, geochemical mobility, and sampling protocols constrain extrapolation between ore domains. This evidence informs hypotheses to test, not tonnage or reserve certification for Laos or Vietnam (Nguyen et al., 2024; Pereira, 2025; Sun et al., 2023; Xiao et al., 2025; Zhang et al., 2020; Zhao, 2025).

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

4. Laos: Projects and the Transition from Exploration to Trial Mining

4.1. Meng Khun/Mengkham and northern provinces

The principal challenge in interpreting the northern Lao frontier is the small proportion of prospectivity claims supported by reproducible project-level figures. Investigations of Meng Khun, Houaphanh, and neighboring weathering belts provide evidence of geological prospectivity and local regolith evolution, but reserves and commercial output must be evaluated separately (Xie et al., 2026; Ye et al., 2025; Liu et al., 2025). The source outline includes an inferred-resource figure stated on an SREO basis. This cannot be generalized as national TREO reserves or treated as saleable HREE.

4.2. Exploration, trial production, and industrial status

The review distinguishes exploration licenses, delineation drilling, resource estimates, metallurgical pilot tests, trial mining, and year-long production at sustained assay and throughput. The Sepon area and northern concessions require dated, project-specific records before their commercial status can be inferred. The difference between reported activity and independently verified products is summarized in Table 2.

Table 2. Comparative reporting status and geological context in Laos and Vietnam

Indicator	Laos	Vietnam
Dominant case-study model	Northern regolith and ion adsorption	Hard rock plus ion adsorption and placers
Public reporting challenge	Project-level assay and trial-to-commercial validation	Resource/reserve reconciliation and plant output
Critical metallurgical assay	Exchangeable REE/SREO by depth and element	Mineralogy, liberation, and individual REE grades
Primary uncertainty	Commercial production and separation statistics	Scale-up, quality of refined products, and commissioning

Note. Qualitative, author-developed comparison; no absent national statistic is interpreted as a zero resource or production value.

Table 2 should not be read as a country ranking. Missing production data, ambiguous product classifications, and changes in reporting standards can create apparent discrepancies without proving either technical success or failure.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

5. Vietnam: From Geological Resources to Limited Commercial Output

5.1. Dong Pao, Nam Xe, and Yen Phu

Dong Pao is relevant for the contrast between substantial mineralized inventories and the absence of a correspondingly mature, validated mine-to-separated-oxide industrial pathway. The mineral portfolio implies selective flotation and hydrometallurgical treatment rather than a universally transferable route (Bui et al., 2025; Jung et al., 2024; Choi et al., 2026). Nam Xe work illustrates the value of sensor sorting and selective comminution before chemical treatment (Cardenas-Vera et al., 2022). Yen Phu studies on REE recovery and radionuclide management underline the need to consider impurity-bearing streams, not simply head grade (Hung et al., 2022; Mends & Chu, 2025).

5.2. Reconciling historical resource and reserve figures

The USGS 2024 Mineral Commodity Summaries reported about 22 million metric tons of rare-earth-oxide reserves for Vietnam; the 2025 edition revised this to about 3.5 million metric tons based on company and government reporting, and the 2026 edition retained 3.5 million metric tons. These are edition-specific national estimates, not project-level reserve declarations under JORC, NI 43-101, or another CRIRSCO-aligned code. Do not interpret the difference as the physical disappearance of 18.5 million tonnes of geological material, or treat it as an independently established loss of economically recoverable inventory (U.S. Geological Survey, 2024, 2025, 2026).

The more important industrial question is whether discrete projects can establish continuous flowsheets that deliver qualified, saleable products. Table 3 translates deposit-specific constraints into necessary tests, rather than presenting announced plant capacity as realized production.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Table 3. Selected REE project and ore-domain verification requirements

System	Geological or processing emphasis	Critical confirmation
Lao ionic-clay targets	Weathered profiles, clay interactions, soluble REO	Depth assays, permeability, verified resource basis
Dong Pao (Vietnam)	REE fluorocarbonates and complex gangue	Domain flotation, cracking, downstream impurity balance
Nam Xe (Vietnam)	Variable mineralization and preconcentration	Sorting, liberation, representative recovery
Yen Phu (Vietnam)	Xenotime-bearing products and potential Th/U	Concentrate assays, NORM deportment, residue plans

Note. Comparative assessment based on the cited deposit literature; not an independently audited project inventory.

An explicit verification ledger should document sampling date, mass balance, mineralogical method, reporting category, ownership and permit status, pilot duration, and specification of any marketed product. The same metrics are required for rigorous comparisons of investment and technology readiness.

Vietnamese mineral occurrences must be examined as distinct ore domains rather than extrapolated from one bulk assay. Processing reports from other deposits are instructive analogs, but neither a national resource table nor a bench-scale result demonstrates sustained domestic oxide output (Pham et al., 2025).

6. Mineralogy, Beneficiation, and Feedstock Quality

6.1. Regolith and exchangeability as process variables

Ion-adsorption materials may respond strongly to clay surface area, cation exchange capacity, competing Al and Fe, and access of lixiviant to micro- and macropores. Leaching of other ionic clays provides valuable mechanistic comparisons without validating an industrial Lao performance claim (Anawati & Azimi, 2023; Azimi, 2025; Cunningham et al., 2025; Huang et al., 2023). Analytical protocols must report total and soluble element vectors along with mineralogical hosts and size fractions. For each horizon and each of Nd, Pr, Dy, Tb, and Y, a representative characterization should disclose total content, operationally exchangeable content, f_exchange,i, and host-phase attribution, rather than treating composite TREO and

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

SREO values as interchangeable. The selected exchange reagent and test conditions must accompany each reported SREO value.

6.2. Hard-rock concentration and variability

Vietnamese fluorocarbonate- and phosphate-rich feeds require particle-scale understanding of mineral liberation, intergrowth, fines generation, and surface chemistry. The appropriate separation window often depends on particle size, pulp pH, collector dose, depressants, and gangue composition rather than a single optimum (Adu et al., 2026; Jung et al., 2024; Choi et al., 2026). A truly representative flowsheet must be tested across the identified ore domains and not evaluated solely on one selected bulk sample.

The broader beneficiation literature underscores the interplay among mineral liberation, surface chemistry, selectivity, feed variability, and fine-particle loss. These studies support a diagnostic test matrix, not an assumption that a published collector or sorting circuit transfers unchanged to Dong Pao or Nam Xe (Adu et al., 2026; Baştürkcü et al., 2022; Cardenas-Vera et al., 2022; Choi et al., 2026; Hung et al., 2020).

Related investigations further show that process selectivity changes with gangue interactions, preconditioning, particle size, and water chemistry; optimization should be tested against a domain-specific variability envelope (Liang et al., 2025; Nguyen et al., 2024; Pereira, 2026e; Pereira, 2026i; Pereira, 2026m).

Complementary studies indicate that percolation efficiency and flotation selectivity depend on fines generation, pore and particle interactions, interfacial chemistry, and ore-domain-specific test conditions. These analogs should guide representative testing and not be presented as independently proven outcomes at Dong Pao or Nam Xe (Shuai et al., 2024; G. Wang et al., 2024; J. Wang et al., 2024; L. Wang et al., 2024; W. Wang et al., 2024).

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

7. Extraction Metallurgy and Process Selectivity

7.1. Salt-assisted ion-exchange leaching

Dilute magnesium salts, ammonium salts, and alternative eluents can displace adsorbed REE ions. Their performance depends on exchange stoichiometry, pH, ionic strength, diffusion, pore architecture, and unwanted release of Al and other cations. Apparent recovery must therefore be paired with a solution-composition balance and time-dependent permeability data (Fan et al., 2021; Feng et al., 2023; Feng et al., 2024; Gao et al., 2023; Huang et al., 2023; Wu et al., 2024). The associated environmental inventory cannot be omitted from process ranking (Pereira, 2026b; L. Wang et al., 2024). Element-resolved metal recovery is R_i (%) = 100 × $m_{i,recovered}$ / $m_{i,feed}$, where the recovered stream and accounting boundary must be stated. Dissolution of Al, Fe, Ca, and Mg should be reported alongside REEs. One possible selectivity index is $S_{REE/Al} = R_{REE} / R_{Al}$, with both recoveries defined using the same mass-balance boundary; this index becomes ill-conditioned when Al recovery approaches zero and must not be reported without uncertainty or detection limits.

7.2. Hard-rock cracking, leaching, and impurity partitioning

For mineral concentrates, upstream upgrading must be integrated with sulfuric or alternative decomposition chemistry, aqueous leaching, precipitation, and multistage purification. Recoveries that appear favorable at the dissolution stage may generate poor final yields or unacceptable Th/U, fluoride, Ca, Ba, or Fe carryover after downstream operations (Judge & Azimi, 2020; Basque et al., 2023; Pereira, 2026a).

Table 4 summarizes principal flowsheet decisions. The corresponding stream-level architecture is shown in Figure 2; both are process-selection guides, not claims of particular commercial installations.

Table 4. Critical process variables for ionic-clay and hard-rock rare-earth extraction

Criterion	Ion-adsorption regolith	Hard-rock REE concentrate
Feedstock definition	SREO/TREO, sorption and depth profile	Phase proportions, liberation, gangue
Primary process	Controlled ion-exchange percolation	Beneficiation and mineral decomposition

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Criterion	Ion-adsorption regolith	Hard-rock REE concentrate
Selectivity metric	Individual REE/Al and REE/Fe response	Individual REE/Th, REE/U and REE/gangue behavior
Scale-up tests	Permeability, hydrology, recycle	Continuous beneficiation, cracking, mass balance
Main environmental load	Residual electrolytes and groundwater	Tailings, reagents, and potentially NORM

Note. Conceptual decision matrix synthesized from ionic-clay leaching and hard-rock processing literature; numerical optimization requires ore-specific validation.

Recovery values are not comparable unless products, dry-feed basis, dissolved impurities, wash liquors, entrainment, solid residues, and recycle inventories are reconciled. Figure 2 makes these omitted branches visible rather than treating the leachate assay as an industrial product.

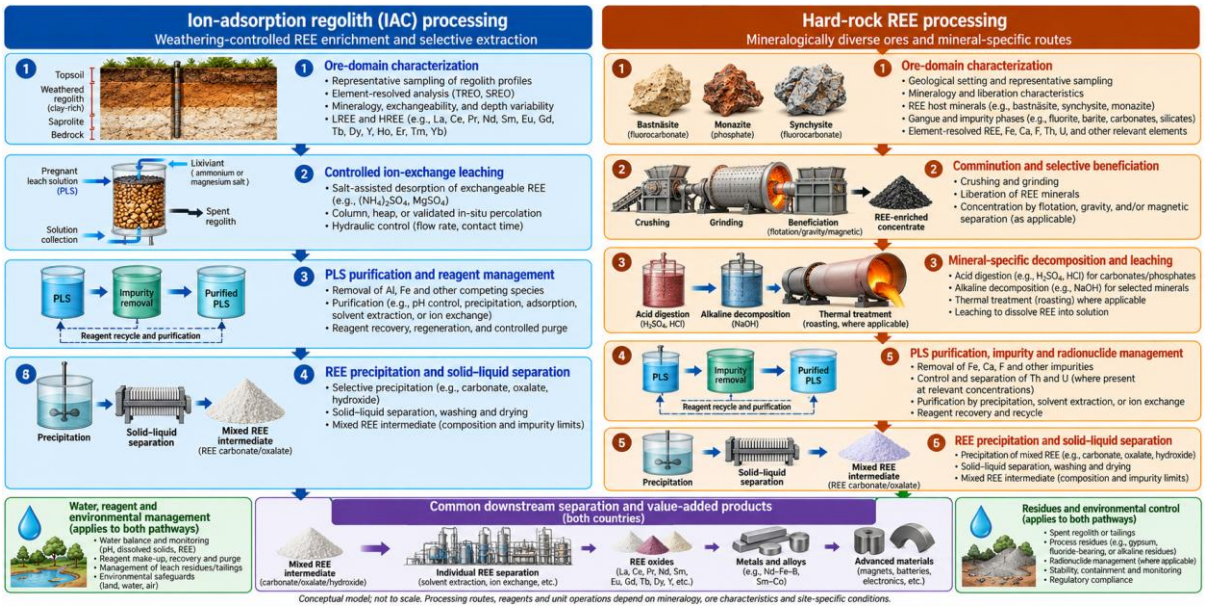


Figure 2. Conceptual process-route comparison: salt-assisted ion exchange for weathered ionic clays and selective upgrading–decomposition–leaching for hard-rock REE feeds.
Note. Original conceptual figure prepared for this review, informed by the cited literature; no previously published artwork was reproduced. An "Adapted from" credit is therefore not applicable.

The principal technical difference is the locus of selectivity. In ionic-clay systems it is dominated by surface exchange and flow accessibility; in hard-rock systems it depends first on mineral separation and then on decomposition chemistry, impurity rejection, and product-specific purification.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Performance evaluation of ionic-clay leaching must couple mass transfer, pore evolution, competitive sorption, and solution chemistry. Report initial and time-dependent hydraulic conductivity or permeability, leachate throughput and pore volumes, swelling and fines migration, plus element-resolved extraction of Nd, Pr, Dy, Tb, and Y (Asubonteng et al., 2025; Cheng et al., 2025; Chen et al., 2023, 2025; Cunningham et al., 2025).

Laboratory ion exchange and column-leaching literature supports a common mechanism-based comparison of competing-ion release, pH and ionic-strength evolution, and recovery versus time or pore volumes. The extraction chemistry and transport conditions should be reported jointly, because high endpoint extraction can coexist with poor selective recovery or hydraulically unsustainable operation (Fan et al., 2021; Feng et al., 2023, 2024; Gan et al., 2023; Gao et al., 2023; Guo et al., 2023; Huang et al., 2023, 2025; Hu et al., 2025; Kang et al., 2024; Ketegenov et al., 2024; Li et al., 2024).

The design boundary must also close the fresh lixiviant input, pregnant solution, recycle, purge, retained salts in solids, and wastewater or groundwater releases. Repeated-cycle experiments should quantify reagent demand and losses, water balance, impurity accumulation, permeability changes, and post-leach hydraulic behavior (Liu et al., 2023, 2024; Long et al., 2025; Meng et al., 2023; Mohamad Sobri et al., 2024, 2025; Negash et al., 2024; Pereira, 2026j, 2026o; Qiu et al., 2022, 2025; Russo et al., 2025; Shalchian et al., 2024).

For hard-rock routes and heterogeneous feeds, reporting should connect ore-domain characterization to mass pull, concentrate grade, element-specific recovery, gangue rejection, fines loss, decomposition efficiency, and impurity deportment. Where Th and U occur, their mass-balance closure $C_{Th/U} = \Sigma m_{Th/U,outputs} / m_{Th/U,feed}$ should be evaluated with analytical uncertainty; transferring radionuclides into a residue is not elimination from the system (Pereira, 2026a, 2026k, 2026n; Shi et al., 2023; Sobri et al., 2023; Tamayo-Soriano et al., 2024; J. Wang et al., 2024; W. Wang et al., 2024).

Additional hydrodynamic, surface-chemical, and geochemical investigations are best used to test mechanisms and identify the necessary measurement envelope; none alone

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

demonstrates continuous, verified Lao or Vietnamese commercial output (G. Wang et al., 2024; L. Wang et al., 2024; Wang et al., 2025; Wu et al., 2023, 2024; Xie et al., 2026; Ye et al., 2025; You et al., 2025; Zeng et al., 2022; Zhang et al., 2023, 2024, 2025; Zhou et al., 2024).

8. Separation, Refining, and the Downstream Gap

8.1. From mixed intermediates to separated oxides

Mixed REE carbonates, mixed oxides, and pregnant leach solutions are intermediates, not demonstrations of individual separated-oxide manufacture. The separation route must specify element-specific assays for Nd, Pr, Dy, and Tb, total recovery, residual metallic and nonmetallic impurities, stable product specifications, lot-to-lot reproducibility, continuous operating hours, reagent balances, and end-user acceptance. The term “magnet grade” must refer to a stated customer or industrial specification for each distinct oxide rather than a generic purity threshold (Dewulf et al., 2022; El Ouardi et al., 2023; Quijada-Maldonado & Romero, 2021).

8.2. How to establish technology maturity without misleading TRL labels

TRL is useful only for a specified unit operation, identified demonstration environment, and dated evidence. Assigning a generic TRL to a country, deposit type, or proposed value chain implies unsupported precision. For REE separation, assess bench selectivity, continuous pilot hours, mass-balance closure, qualified product lots, stable utilities, and customer acceptance. These indicators enable comparison without inventing deployment status.

Downstream alternatives include solvent extraction, ion exchange, sorbents, and membrane-based or crystallization-assisted fractionation. Their laboratory selectivity must not be equated with qualified mixed or individual rare-earth oxide products under continuous operation (Basque et al., 2023; Dewulf et al., 2022; El Ouardi et al., 2023; Hung et al., 2022; Judge et al., 2020).

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Chemical separation studies contribute differently to downstream qualification: solvent extraction and ion exchange inform distribution ratios, selectivity, and stage requirements, whereas sorbents and emerging separations expand potential selective-recovery configurations. None by itself confirms saleable individual oxide production without sustained process operation and product assays (Jung et al., 2024; Malki et al., 2024; Mends et al., 2025; Merroune et al., 2024; Pereira, 2026n; Rodríguez Varela et al., 2025; Rybak et al., 2024).

Qualification evidence should additionally document recycle stability, impurity removal and build-up, water and reagent losses, reliable product chemistry across lots, and mass-balance reconciliation from mixed feed to separated product. Analog separation research provides test strategies, but cannot establish operating separation capacity in either country (Saravanan et al., 2025; Souza et al., 2025; Tian et al., 2025; Wang et al., 2025; Yang et al., 2020).

9. China Linkages, Trade, and Market Position

9.1. Feedstock origins versus processing destinations

A nominal increase in Lao or Vietnamese REE mining can diversify the origin of ore while leaving the downstream separation, metal production, and magnet chain geographically concentrated. The location of the last high-value conversion, not merely that of the mine, is therefore essential to assessment of supply security (International Energy Agency, 2025; Xu et al., 2024; Depraiter et al., 2025; Woods, 2025).

IEA data for 2024 show that China accounted for approximately 60% of mined magnet rare earths, 91% of refined magnet rare earths, and 94% of sintered permanent magnets; these figures specifically concern Nd, Pr, Dy, and Tb and must not be generalized to all 17 REEs (International Energy Agency, 2026b). The IEA Global Critical Minerals Outlook 2026 reports modest improvement in rare-earth refining diversification during 2025 owing to new US projects and increased Malaysian output, but still identifies a large imbalance between planned

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

mining, separation, and downstream manufacturing capacities (International Energy Agency, 2026a).

9.2. Trade policy and strategic partnerships

Government plans and partnerships may expand future options, but distinguish announcements from funded projects, operating plants, product qualification, and binding offtake agreements. Studies of international critical-mineral policies offer a framework for evaluating these claims (Rosa & Yunita, 2026; Zhiltsov & Hoang, 2025; Kosajan et al., 2025). Figure 3 shows two meanings of diversification.

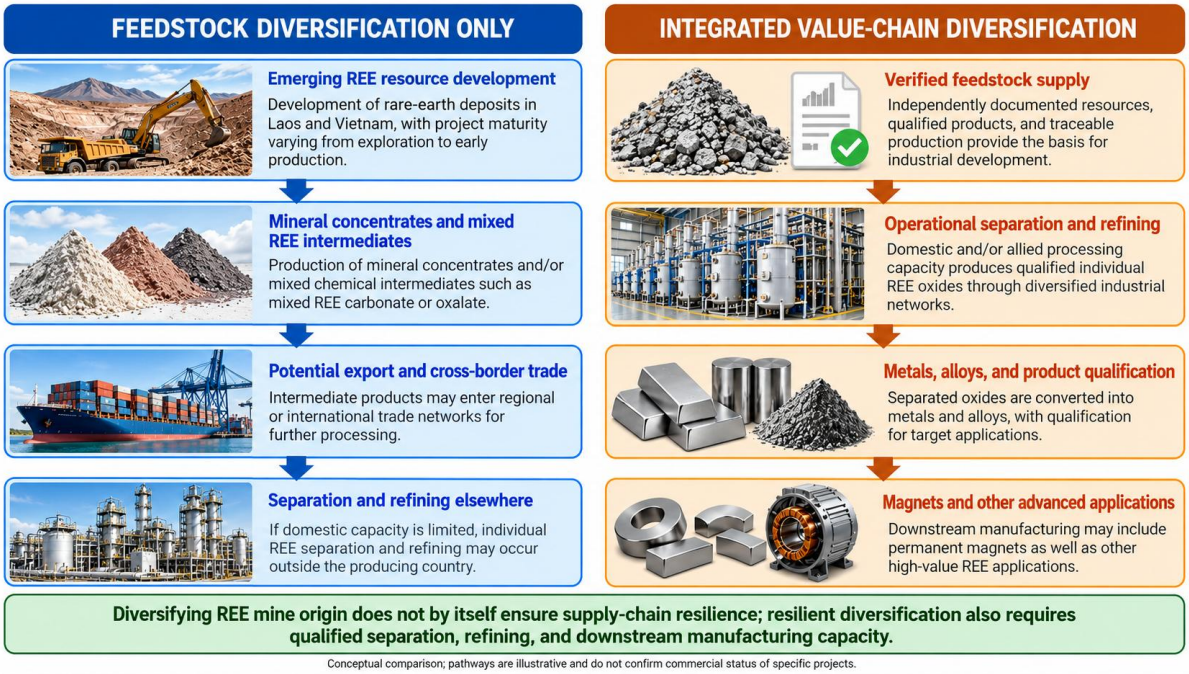


Figure 3. Two distinct diversification outcomes: new origins for REE-containing feedstocks versus new independent conversion and manufacturing chains.

Note. Original conceptual figure prepared for this review, informed by the cited literature; no previously published artwork was reproduced. An "Adapted from" credit is therefore not applicable. Figure 3 also illustrates why customs data should not be converted automatically into contained REO tonnage. Intermediate compositions and purity classes vary, and the same materials can cross borders several times before becoming separate oxides or alloys.

A reproducible trade conversion requires the exact HS code and revision, declared gross shipment mass, identified commodity class, measured REO fraction, any oxidation/conversion

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

factor, country of transformation, potential re-export status, and uncertainty. In the absence of product composition, gross mass or customs value cannot be converted into contained rare-earth-oxide mass or national mining output. The auditable physical chain is ore → concentrate → mixed REE chemical → separated oxide → metal → alloy → magnet, and commercial status must be verified independently at each stage.

Trade-network and criticality research highlights a distinction between changes in ore origin and changes in processing control. The review therefore separates feedstock diversification, refining diversification, economic dependence, and independently verifiable domestic value addition (Attílio et al., 2025; Demir et al., 2026; Depraiter et al., 2025; Diao et al., 2024; Guo et al., 2025).

Additional supply-security accounts underline that export values, inferred mine tonnage, and mineral reserves cannot be interchanged in geopolitical interpretation (Guo et al., 2024; Hamed et al., 2024; Kosajan et al., 2025; Orlova et al., 2024; Pereira, 2026c).

Additional supply-security accounts underline that export values, inferred mine tonnage, and mineral reserves cannot be interchanged in geopolitical interpretation (Pereira, 2026h; Quijada-Maldonado et al., 2021; Rosa et al., 2026; Tetzner & Campos, 2026; Vo et al., 2024).

Additional supply-security accounts underline that export values, inferred mine tonnage, and mineral reserves cannot be interchanged in geopolitical interpretation (Woods, 2025; Xu et al., 2024; Zhiltsov et al., 2025).

10. Environmental Burden, Water, NORM, and Social License

10.1. Hydraulic and chemical risks in regolith leaching

The apparently simple front end of ionic-clay extraction can mask significant long-term environmental liabilities. Construction, operation, and closure must monitor hydrological containment, sulfate and ammonium inventories, soil salt accumulation, unstable slopes, and infiltration into nearby watersheds (Han et al., 2023; Feng & Wang, 2024; Wang et al., 2024;

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Phetmany et al., 2026). Direct Lao measurements should remain spatially and temporally specific and should not be generalized to every deposit. A documented Lao pilot-site cyanide incident should be treated as site-specific evidence of chemical-release risk rather than proof that cyanide is an intrinsic reagent of ion-adsorption REE leaching. Monitoring should distinguish pre-project baseline, operational conditions, incidents, remediation, and closure and include upstream controls, downstream gradients, dates, flow conditions, dissolved and total metals, and analyte-specific reagent measurements.

10.2. Hard-rock residue chemistry and NORM

Vietnamese concentrates containing radioactive minerals demand an explicit radionuclide deportment balance through beneficiation, cracking, leaching, precipitation, and solid-waste storage. Thorium separation may improve solution quality but transfers radiological inventory to another stream rather than destroying it (Basque et al., 2023; Mends & Chu, 2025; Yang et al., 2020). Tailings, acidic residues, and fluorine-rich streams likewise require site-specific controls. A quantitative inventory should reconcile Th and U in feed, concentrates, solutions, precipitates, tailings, dust, and purge streams with uncertainty; a purified REE solution alone cannot demonstrate radionuclide elimination.

These risk mechanisms are compared in Table 5, where prevention and monitoring requirements differ by process family.

Table 5. Process-linked environmental safeguards and evidence gaps

Risk	Ionic-clay pathway	Hard-rock pathway
Water quality	Containment; lixiviants, modifiers, residual electrolytes, and site-specific additives; upstream/downstream wells	Effluent chemistry, recycle, sediment control
Solid residues	Residual salt and disturbed regolith	Tailings, acid residues, fluoride and NORM
Geotechnical stability	Infiltration, slope movement and subsidence	Tailings and residue storage stability
Closure assurance	Long-term hydrology and revegetation	Chemical immobilization and residue stewardship

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Risk	Ionic-clay pathway	Hard-rock pathway
Evidence need	Baseline–operation–incident–recovery–closure monitoring; hydrology, residual salts, and groundwater	Stream-specific radionuclide and impurity balances

Note. Author-derived risk-screening matrix. Cyanide has been reported for a particular Lao pilot-operation incident and is not assumed to be an intrinsic or universal ionic-clay lixiviant. Listed risks are not evidence of non-compliance by any specific project.

Table 5's comparison underscores that "low-energy leaching" and "environmentally safe leaching" are not synonyms. The correct sustainability boundary encompasses input salts and acids, energy and water use, emissions, residue stability, remediation, and ongoing monitoring.

Environmental and safety analogs clarify plausible failure modes, including subsurface fluid escape, reagent persistence, slope instability, and trace-element mobilization. Evidence from different commodities or jurisdictions supports hazard screening, not as observed impacts of Lao or Vietnamese REE operations (Guo et al., 2024; Han et al., 2023; Krasavtseva et al., 2025; Liu et al., 2025).

Further studies support integrated monitoring of water, solids, chemicals, radiation, and closure, with measured baselines and location-specific risk pathways (Pereira, 2026b; Pereira, 2026f; Phetmany et al., 2026; Rezaei et al., 2025; Sager et al., 2024).

Further studies support integrated monitoring of water, solids, chemicals, radiation, and closure, with measured baselines and location-specific risk pathways (Wang et al., 2025; Zhao et al., 2024).

11. Governance, Economics, Infrastructure, and Project Bankability

11.1. Decision-critical operating evidence

Capital access and market entry depend on demonstrated feedstock availability, distribution of contained value by element, reproducible mass balance, logistics, utilities, reagent imports, residual liabilities, and realistic market specifications. Sensitivity to grade, exchangeable fraction, recovery, reagent use, and downstream penalties may dominate simple

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

gross contained-value calculations (International Energy Agency, 2025; Kosajan et al., 2025; Balaram, 2023).

11.2. Governance and traceability

For both countries, transparently dated concessions, permits, contracts, beneficial ownership, environmental authorizations, and independent product assays are central to market credibility. The most relevant institutional bottleneck differs: Laos has especially limited systematic visibility into emerging extraction projects, whereas Vietnam faces the challenge of turning a comparatively well-documented geological base into certified, bankable integrated operations (Zhiltsov & Hoang, 2025; Rosa & Yunita, 2026).

Secondary-resource and recovery studies offer options for regional process integration, reagent recovery, and circularity. The associated balances, impurity suites, and product specifications depend on the feed and cannot be imported as numerical design bases without verification (Azimi, 2025; Pereira, 2026d; Pereira, 2026g; Pereira, 2026l).

12. Critical Comparative Synthesis and Future Gaps

12.1. Laos–Vietnam REE value-chain readiness

The proposed Laos–Vietnam REE Value-Chain Readiness (LV-REE-VCR) framework distinguishes geological confidence, resource classification, metallurgical validation, separation qualification, environmental assurance, infrastructure, financing, traceability, and downstream integration. It is a qualitative diagnostic checklist, not a quantitative country league table. Because each dimension requires different evidence, unmeasured items should be left unscored rather than assigned arbitrary values (Chen et al., 2024; International Energy Agency, 2025; Azimi, 2025). Figure 4 presents the framework.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

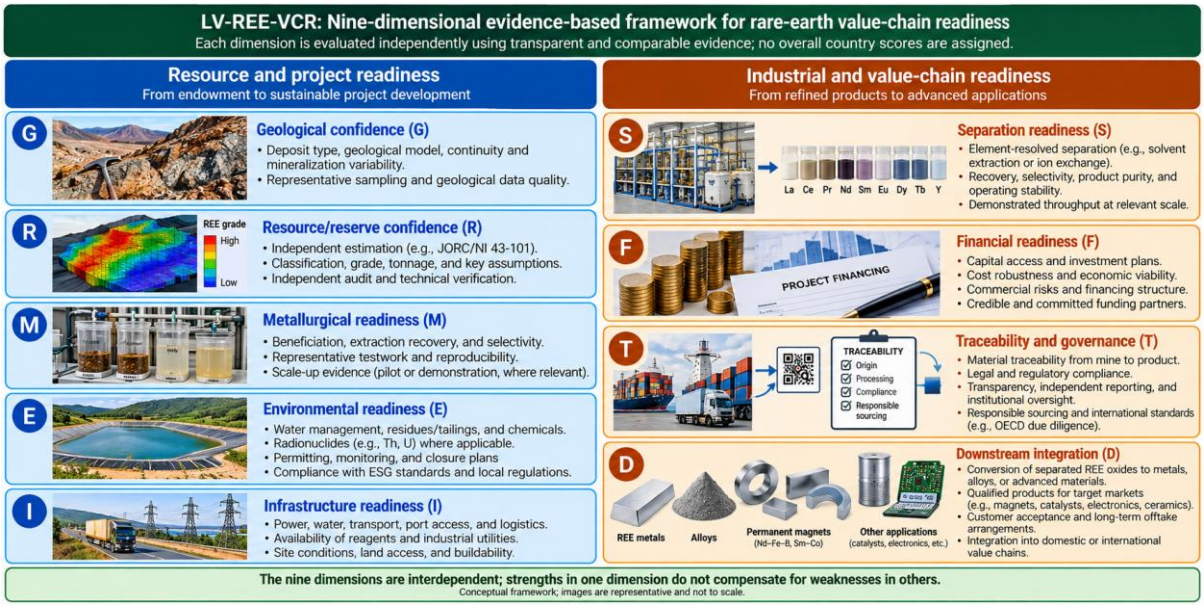


Figure 4. Conceptual LV-REE-VCR diagnostic architecture, separating evidence of deposit and process readiness from evidence of commercial downstream integration.

Note. Original conceptual figure prepared for this review, informed by the cited literature; no previously published artwork was reproduced. An "Adapted from" credit is therefore not applicable.

As Figure 4 indicates, strong exploration or leaching results cannot compensate for absent separation capability or inadequate environmental safeguards. This noncompensatory interpretation is particularly important when exploring financing or government policy priorities.

12.2. Priority research agenda and future outlook

In Laos, priorities are independent national and project inventories, standardized TREO and SREO measurements, element-resolved HREE occurrence, representative field percolation, reagent recycling, and validated groundwater-impact monitoring (Liu et al., 2025; Xie et al., 2026; Ye et al., 2025). In Vietnam, priorities are audited resource-to-reserve conversion, ore-domain beneficiation, continuous cracking and impurity treatment, Th/U management, and proof of sustained output at separated-oxide specifications (Bui et al., 2025; Hung et al., 2022; Cardenas-Vera et al., 2022).

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

An integrated market program should map whether Nd, Pr, Dy, and Tb enter mixed-concentrate export, chemical separation, metallization, alloy production, or magnet manufacturing. Research on dysprosium supply, secondary alternatives, and shifting mining-resource portfolios provides useful analytical context, but country-specific plant performance must be supported by separate evidence (Pereira, 2026; Balaram, 2023; Xu et al., 2024).

Broader assessments provide methodological context for evaluating technology selection and value-chain development. They are interpreted as comparative or conceptual contributions rather than direct operational evidence from the two countries (Anawati et al., 2023; Feng et al., 2024; International Energy Agency, 2025; U.S. Geological Survey, 2024; U.S. Geological Survey, 2025).

These additional sources broaden the comparison; conclusions remain conditional on independent validation of geography-specific claims (U.S. Geological Survey, 2026; Xue et al., 2024; Özer et al., 2025).

13. Conclusions and Outlook

Laos and Vietnam are strategically relevant but structurally different emerging rare-earth jurisdictions. Laos shows promising ion-adsorption exploration potential, including possible contributions of heavy rare earth elements, but requires more transparent, independently qualified project and production evidence. Vietnam has a diverse and comparatively developed geological knowledge base, yet conversion into sustained mine-to-refined-product activity remains a central industrial challenge.

The key determinant of future value will not be extraction volume alone. It will be the capacity to characterize recoverable REE inventories, operate selective and environmentally controlled process routes, supply consistently qualified separated products, and trace value creation through subsequent conversion stages. Diversification of mineral origins is useful, but durable supply security depends on credible alternatives in refining and downstream manufacturing.

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Declarations

Funding: Funding information was not provided to the revising editor. The corresponding author must confirm the final funding statement before submission.

Conflicts of interest: The corresponding author must review and approve a truthful conflict-of-interest statement before submission; no absence of conflicts has been presumed.

Data availability: No original experimental dataset was produced for this critical review. The cited public literature and institutional records are the documentary basis.

Author contributions: The corresponding author must confirm the final CRediT roles and authorship responsibilities before submission.

AI-assisted writing disclosure: AI-assisted editorial revision and language support were used. The corresponding author remains responsible for scientific accuracy, citations, interpretation, and compliance with the target journal's disclosure policy.

References

Adu, P. C. O., Dadzie, R. A., Morrissey, L., Zanin, M., Skinner, W., & Abaka-Wood, G. B. (2026). Mineralogical constraints and beneficiation perspectives for ultrafine rare earth elements in flotation tailings. Powder Technology, 479, 122570. https://doi.org/10.1016/j.powtec.2026.122570

Anawati, J., & Azimi, G. (2023). Extraction of rare earth elements from a South American ionic clay. Journal of Rare Earths, 41(9), 1408–1418. https://doi.org/10.1016/j.jre.2022.10.007

Asubonteng, D., Mahtar, A., Zaidi, S. T. H., Ahsan, H. A., Zegaoui, Y., Mehmood, A., Arthur, E., Wirzal, M. D. H. B., & Bustam, M. A. (2025). Leaching enhancement of rare earth elements from ion-adsorption clay using choline acetate and betaine hydrochloride. Journal of Molecular Liquids, 437, 128396. https://doi.org/10.1016/j.molliq.2025.128396

Attílio, L. A., Faria, J. R., & Silva, E. (2025). Critical minerals, clean tech, geopolitical risk and the global energy transition: An exploration of the Chinese influence on rare earth and lithium markets through the GVAR model. Cambridge Prisms: Energy Transitions, 1, e7. https://doi.org/10.1017/etr.2025.10005

Azimi, G. (2025). Technological advancements in rare earth elements recovery from ionic clays: A comprehensive review. Hydrometallurgy, 231, 106414. https://doi.org/10.1016/j.hydromet.2024.106414

Balaram, V. (2023). Potential future alternative resources for rare earth elements: Opportunities and challenges. Minerals, 13(3), 425. https://doi.org/10.3390/min13030425

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Basque, J., Lavoie, J., Reynier, N., & Larivière, D. (2023). Quantitative separation of thorium from rare earth elements and uranium in a rare earth element sulfuric acid leachate using cloud point extraction. Microchemical Journal, 190, 108724. https://doi.org/10.1016/j.microc.2023.108724

Baştürkcü, E., Şavran, C., Yüce, A. E., & Timur, S. İ. (2022). Revealing the effects of mechanical attrition applied on Eskisehir-Beylikova REE ore utilizing MLA. Minerals Engineering, 186, 107733. https://doi.org/10.1016/j.mineng.2022.107733

Bui, T. T., Watanabe, Y., Tupaz, C. A. J., Echigo, T., Aoki, S., & Hoshino, M. (2025). Rare-earth mineralization in Dong Pao deposit, Laichau Province, Vietnam. Resource Geology, 75(1), e70006. https://doi.org/10.1111/rge.70006

Cardenas-Vera, A., Hesse, M., Möckel, R., Merker, R. G., Heinig, T., & Phan, Q. V. (2022). Investigation of sensor-based sorting and selective comminution for pre-concentration of an unusual parisite-rich REE ore, South Namxe, Vietnam. Minerals Engineering, 177, 107371. https://doi.org/10.1016/j.mineng.2021.107371

Chen, H., Chen, L., Zhang, L., & Guo, M. (2023). Spatial heterogeneity of rare earth elements: Implications for the topsoil of regional ion-adsorption type rare earth deposit areas in southern China. Minerals, 13(6), 784. https://doi.org/10.3390/min13060784

Chen, P., Ilton, E. S., Wang, Z., Rosso, K. M., & Zhang, X. (2024). Global rare earth element resources: A concise review. Applied Geochemistry, 175, 106158. https://doi.org/10.1016/j.apgeochem.2024.106158

Chen, Z., Wang, H., Chi, R., & Zhang, Z. (2025). Adsorption characteristics of praseodymium and neodymium with clay minerals. Minerals, 15(10), 1051. https://doi.org/10.3390/min15101051

Cheng, Y., Zhang, D., Gao, X., Yu, J., Chi, R., Deng, B., & Zhou, F. (2025). Influence of humic acid on the swelling inhibition of clay minerals and process optimization. Minerals, 15(10), 1062. https://doi.org/10.3390/min15101062

Choi, J., Hong, G., & Kim, W. (2026). Defining an operational selectivity window for rare-earth flotation using a Box–Behnken design. Scientific Reports, 16, 17455. https://doi.org/10.1038/s41598-026-47746-6

Cunningham, S., Grammatikopoulos, T., Almusned, B., Henderson, J. D., & Azimi, G. (2025). Comprehensive characterization and extraction implications of ion adsorption rare earth deposit from a South American source. Scientific Reports, 15, 29022. https://doi.org/10.1038/s41598-025-14891-3

Demir, I., Ayten, A. M., Top, S., Altiner, M., & Kursunoglu, S. (2026). Rare earth elements in the global economy: Usage, recovery, and the quest for supply security—A review. Mining, Metallurgy & Exploration, 43, 2061–2092. https://doi.org/10.1007/s42461-026-01559-3

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Depraiter, L., Goutte, S., & Porcher, T. (2025). Geopolitical risk and the global supply of rare earth permanent magnets: Insights from China's export trends. Energy Economics, 146, 108496. https://doi.org/10.1016/j.eneco.2025.108496

Dewulf, B., Riaño, S., & Binnemans, K. (2022). Separation of heavy rare-earth elements by non-aqueous solvent extraction: Flowsheet development and mixer-settler tests. Separation and Purification Technology, 290, 120882. https://doi.org/10.1016/j.seppur.2022.120882

Diao, H., Yang, H., Tan, T., Ren, G., You, M., Wu, L., Yang, M., Bai, Y., Xia, S., Song, S., Quintana, M., Liu, L., & Xue, Q. (2024). Navigating the rare earth elements landscape: Challenges, innovations, and sustainability. Minerals Engineering, 216, 108889. https://doi.org/10.1016/j.mineng.2024.108889

El Ouardi, Y., Virolainen, S., Mouele, E. S. M., Laatikainen, M., Repo, E., & Laatikainen, K. (2023). The recent progress of ion exchange for the separation of rare earths from secondary resources—A review. Hydrometallurgy, 218, 106047. https://doi.org/10.1016/j.hydromet.2023.106047

Fan, B., Zhao, L.-S., Feng, Z.-Y., Liu, D.-P., Yin, W.-Q., Long, Z.-Q., & Huang, X.-W. (2021). Leaching behaviors of calcium and magnesium in ion-adsorption rare earth tailings with magnesium sulfate. Transactions of Nonferrous Metals Society of China, 31(1), 288–296. https://doi.org/10.1016/S1003-6326(21)65495-X

Feng, J., Wu, X., Gao, Z., Sun, W., Zhou, F., & Chi, R. (2023). Leaching behavior of rare earth elements and aluminum from weathered crust elution-deposited rare earth ore with ammonium formate inhibitor. Minerals, 13(10), 1245. https://doi.org/10.3390/min13101245

Feng, J., Wu, X., Zhou, F., & Chi, R. (2024). Role of calcium chloride on the eluting process of residual ammonium from weathered crust elution-deposited rare earth ore tailings. Minerals, 14(5), 521. https://doi.org/10.3390/min14050521

Feng, X., & Wang, X. (2024). Characteristics of electrical resistance alteration during in situ leaching of ion-adsorption-type rare earth ore. Minerals, 14(1), 92. https://doi.org/10.3390/min14010092

Gan, L., Yan, B., Liu, Y., Gao, Y., Yin, C., Zhu, L., Tan, S., Ding, D., & Jiang, H. (2023). Geochemical and mineralogical characteristics of ion-adsorption type REE mineralization in the Mosuoying granite, Panxi area, southwest China. Minerals, 13(11), 1449. https://doi.org/10.3390/min13111449

Gao, Z., Rao, Y., Shi, L., Xiang, R., & Yang, Z. (2023). Effect of magnesium sulfate solution on pore structure of ionic rare earth ore during leaching process. Minerals, 13(2), 294. https://doi.org/10.3390/min13020294

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Guo, C., Hou, S., Wang, W., & Li, Q. (2024). Effect of an environment-friendly depressant on the flotation of bastnaesite and fluorite. Minerals, 14(2), 165. https://doi.org/10.3390/min14020165

Guo, Q., & Liu, J. (2025). Study on the measurement of China's rare earth products' international market power and influencing factors. Humanities and Social Sciences Communications, 12, 1760. https://doi.org/10.1057/s41599-025-06047-5

Guo, Q., & Wu, Y. (2024). Assessing China's rare earth supply security. Resources Policy, 95, 105177. https://doi.org/10.1016/j.resourpol.2024.105177

Guo, Q., Li, Z., Pan, J., Li, B., Zhao, L., Liu, D., Zheng, X., & Wang, C. (2023). Leaching mechanism of aluminum during column leaching of ion-adsorption rare earth ore using magnesium sulfate. Minerals, 13(3), 401. https://doi.org/10.3390/min13030401

Guo, W., Zhao, Z., Wang, C., Wang, D., Chen, X., Dang, X., Zhang, W., & Zhao, C. (2024). Micro-topographic controls on rare earth element accumulation and fractionation in weathering profiles: Case study of ion-adsorption rare earth element deposit in Hedi, Zhejiang Province, China. Minerals, 14(11), 1178. https://doi.org/10.3390/min14111178

Guo, Z., Wang, H., Liu, Q., Luo, F., & Liu, Y. (2024). Microstructure evolution law of ionic rare earth at different depths in in situ leaching mine site. Minerals, 14(6), 570. https://doi.org/10.3390/min14060570

Hamed, M. M., Turan, H. H., & Elsawah, S. (2024). Balancing supply diversification and environmental impacts: A system dynamics approach to de-risk rare earths supply chain. Resources Policy, 92, 105038. https://doi.org/10.1016/j.resourpol.2024.105038

Han, M., Rao, Y., Nie, W., Wang, D., Wu, F., & Shi, L. (2023). An early warning system for landslide risks in ion-adsorption rare earth mines: Based on real-time monitoring of water level changes in slopes. Minerals, 13(2), 265. https://doi.org/10.3390/min13020265

Han, Z., Lu, H., Zhang, B., Cheng, Z., Fu, W., Lao, C., & Xu, C. (2023). Delineating preliminary prospective areas of ion-adsorption rare earth deposits with stream sediments geochemical mapping in South China. Journal of Asian Earth Sciences, 243, 105520. https://doi.org/10.1016/j.jseaes.2022.105520

Hu, M., Shao, Y., & Chen, G. (2025). Kinetics of ion exchange in magnesium sulfate leaching of rare earths and aluminum from ionic rare earth ores. Minerals, 15(3), 290. https://doi.org/10.3390/min15030290

Huang, J., Zhang, L., Yu, W., Chen, J., Li, X., Li, Q., Liao, T., & Mo, X. (2025). Recovery of rare earth elements from calciothermic reduction slag by sulfation roasting–water leaching method. Minerals, 15(10), 1025. https://doi.org/10.3390/min15101025

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Huang, L., Zou, Z., Liu, S., Liu, L., Xiao, W., Qian, Y., Alam, S., & Huang, W. (2023). Investigation of hydrated Dy(III) and MgSO4 leaching agent ion adsorption on (001) surface of montmorillonite: A study using density functional theory. Minerals, 13(6), 831. https://doi.org/10.3390/min13060831

Huang, Y., Long, P., Wang, G., Luo, S., Shi, Y., Zhang, C., & Lan, X. (2023). Ion-exchange model for the leaching process of ion-adsorption-type rare-earth ores considering the influence of anions. Minerals, 13(12), 1475. https://doi.org/10.3390/min13121475

Hung, N. T., Thuan, L. B., Thanh, T. C., Thuy, N. T., Tra, D. T. T., Khoai, D. V., Watanabe, M., Minh, P. Q., Than, H. S., Vuong, N. D., Phuc, D. V., Lee, J.-Y., Jeon, J. H., & Jyothi, R. K. (2022). Selective recovery of thorium and uranium from leach solutions of rare earth concentrates in continuous solvent extraction mode with primary amine N1923. Hydrometallurgy, 211, 105933. https://doi.org/10.1016/j.hydromet.2022.105933

Hung, N. T., Thuan, L. B., Thanh, T. C., Watanabe, M., Nhuan, H., Khoai, D. V., Thuy, N. T., Tung, N. V., Aoyagi, N., Tra, D. T. T., Minh, N. T., Jha, M. K., Lee, J.-Y., & Jyothi, R. K. (2020). Optimization of sulfuric acid leaching of a Vietnamese rare earth concentrate. Hydrometallurgy, 191, 105195. https://doi.org/10.1016/j.hydromet.2019.105195

International Energy Agency. (2025). Global critical minerals outlook 2025. https://www.iea.org/reports/global-critical-minerals-outlook-2025

International Energy Agency. (2026a). Global critical minerals outlook 2026. https://www.iea.org/reports/global-critical-minerals-outlook-2026

International Energy Agency. (2026b). Rare earth elements: Pathways to secure and diversified supply chains. https://www.iea.org/reports/rare-earth-elements

Jiang, Z., He, N., Hu, L., Liu, Y., Gong, J., & Zhao, H. (2025). Analysis of occurrence states of rare earth elements in the carbonatite deposits in China. Minerals, 15(8), 866. https://doi.org/10.3390/min15080866

Judge, W. D., & Azimi, G. (2020). Recent progress in impurity removal during rare earth element processing: A review. Hydrometallurgy, 196, 105435. https://doi.org/10.1016/j.hydromet.2020.105435

Jung, M., Tadesse, B., Dick, C., Logan, A., Dyer, L., & Albijanic, B. (2024). Understanding the role of water quality in separation of rare earth minerals from iron oxide minerals in a flotation circuit. Minerals Engineering, 205, 108461. https://doi.org/10.1016/j.mineng.2023.108461

Kang, S., Ling, B., Liang, X., Wang, G., Xu, J., Xu, Y., Zhu, R., Wei, J., Zhu, J., & He, H. (2024). Recovery of rare earth elements from ion-adsorption deposits using

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

electrokinetic technology: The soil conductivity mechanism study. Minerals, 14(5), 491. https://doi.org/10.3390/min14050491

Ketegenov, T., Kamunur, K., Mussapyrova, L., Batkal, A., & Nadirov, R. (2024). Enhancing rare earth element recovery from coal ash using high-voltage electrical pulses and citric acid leaching. Minerals, 14(7), 693. https://doi.org/10.3390/min14070693

Kosajan, V., Wen, Z., & Wang, X. (2025). Criticality assessment and management policy analysis of rare earth elements. Journal of Industrial Ecology, 29(1), 344–357. https://doi.org/10.1111/jiec.13601

Krasavtseva, E., Sandimirov, S., Elizarova, I., Malysheva, M., Makarov, D., & Kaganovich, N. (2025). Rare earth elements in bottom sediments of the northern part of Lake Umbozero, Murmansk Region, Russia. Minerals, 15(9), 973. https://doi.org/10.3390/min15090973

Li, J., Xiao, Y., Feng, X., Wang, J., Ma, Z., Yao, R., Zhai, Y., & Tian, L. (2024). Leaching of ion adsorption rare earths and the role of bioleaching in the process: A review. Journal of Cleaner Production, 143067. https://doi.org/10.1016/j.jclepro.2024.143067

Liang, H., Zhang, P., Jin, Z., Medley, A., & DePaoli, D. (2025). Processing of a phosphate flotation tails for recovery of rare earths and phosphate. Minerals, 15(9), 900. https://doi.org/10.3390/min15090900

Liu, D., Yan, W., Zhang, Z., Guo, W., & Chi, R. (2023). Study on continuously weakening mechanism of heap leaching velocity of weathered rare earth ores with the increase of ore burial depth. Minerals, 13(4), 581. https://doi.org/10.3390/min13040581

Liu, J., Han, Z., Dong, C., Wei, X., & Chen, Y. (2025). Geochemical survey of stream sediments and stream water for ion-adsorption type rare earth deposits (IAREDs): A pilot study in Jiaping IARED, Guangxi, South China. Minerals, 15(6), 642. https://doi.org/10.3390/min15060642

Liu, W., Li, Y., Wang, X., Cui, L., Zhao, Z., Liu, C., & Xu, Z. (2022). Weathering stage and topographic control on rare earth element (REE) behavior: New constraints from a deeply weathered granite hill. Chemical Geology, 610, 121066. https://doi.org/10.1016/j.chemgeo.2022.121066

Liu, X.-R., Liu, W.-S., Zhang, M., Jin, C., Ding, K.-B., Baker, A. J. M., Qiu, R.-L., Tang, Y.-T., & Wang, S.-Z. (2024). Organic-mineral colloids regulate the migration and fractionation of rare earth elements in groundwater systems impacted by ion-adsorption deposits mining in South China. Water Research, 256, 121582. https://doi.org/10.1016/j.watres.2024.121582

Long, F., Chen, W., Zhang, Z., & Chi, R. (2025). Effects of ore particle size distribution on rare earth leaching process of weathered crust elution-deposited rare earth ores. Minerals, 15(2), 149. https://doi.org/10.3390/min15020149

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Malki, M., Mitiche, L., Sahmoune, A., & Fontàs, C. (2024). New insights on Y, La, Nd, and Sm extraction with bifunctional ionic liquid Cyphos IL 104 incorporated in a polymer inclusion membrane. Membranes, 14(9), 182. https://doi.org/10.3390/membranes14090182

Mends, E. A., & Chu, P. (2025). Radionuclide removal in rare earth mineral processing: A review of existing methods and emerging biochemical approaches using siderophores. Minerals, 15(12), 1308. https://doi.org/10.3390/min15121308

Meng, X., Zhao, H., Zhao, Y., Shen, L., Gu, G., & Qiu, G. (2023). Heap leaching of ion adsorption rare earth ores and REEs recovery from leachate with lixiviant regeneration. Science of the Total Environment, 898, 165417. https://doi.org/10.1016/j.scitotenv.2023.165417

Merroune, A., Ait Brahim, J., Berrada, M., Essakhraoui, M., Achiou, B., Mazouz, H., & Beniazza, R. (2024). A comprehensive review on solvent extraction technologies of rare earth elements from different acidic media: Current challenges and future perspectives. Journal of Industrial and Engineering Chemistry, 139, 1–17. https://doi.org/10.1016/j.jiec.2024.04.042

Mohamad Sobri, N. A., & Harun, N. (2025). Mathematical modelling of rare earth elements recovery by ion exchange leaching from ion adsorption clays. Journal of Chemical Engineering and Industrial Biotechnology, 11(1). https://doi.org/10.15282/jceib.v11i1.12401

Mohamad Sobri, N. A., Harun, N., & Mohd Yunus, M. Y. (2024). A review of the ion exchange leaching method for extracting rare earth elements from ion adsorption clay. Chemical Engineering Research and Design, 208, 94–114. https://doi.org/10.1016/j.cherd.2024.06.023

Negash, B. M., Effiong, A. J., Khan, H. W., & Zulkifli, N. I. (2024). Ion-adsorbed REE clays: Swelling challenges and future solutions. Journal of Molecular Liquids, 403, 124849. https://doi.org/10.1016/j.molliq.2024.124849

Nguyen, K. T., Nguyen, B. Q., Nguyen, C. T. H., Pham, C. N., Duong, L. T., Nguyen, M. V. N., Luu, H. T. V., & Dao, N. N. (2024). A beneficiation study to recover xenotime minerals from rich-iron-silicate ores. The Canadian Journal of Chemical Engineering, 102(1), 428–437. https://doi.org/10.1002/cjce.25038

Nguyen, T. A., Yang, X., Tran, T. A., Tran, M. D., Vu, T. H., & Zhao, Z. (2024). Mineralogy and geochronology of pegmatites in the Kontum Massif, Central Vietnam: Implications for evolution of rare-metal mineralization. Lithos, 107747. https://doi.org/10.1016/j.lithos.2024.107747

Orlova, S., & Rassõlkin, A. (2024). Permanent magnets in sustainable energy: Comparative life cycle analysis. Energies, 17(24), 6384. https://doi.org/10.3390/en17246384

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Özer, M., Gümüş, G., Unluer, A. T., Doner, Z., Özdamar, Ş., Kökkılıç, O., & Burat, F. (2025). Characterization and enrichment of rare earth element and heavy mineral-bearing fractions from the Hantepe placer deposit, Çanakkale, Türkiye. Minerals, 15(12), 1293. https://doi.org/10.3390/min15121293

Pereira, A. C. (2025). Processing technologies for rare earth elements from peralkaline igneous deposits: A systematic review. Revista Multidisciplinar do Nordeste Mineiro, 21(2), 1–44. https://doi.org/10.61164/p8v9aq27

Pereira, A. C. (2026a). Agglomeration of fine ores for heap leaching: Mechanisms, design parameters, and scale-up limitations. IKR Journal of Engineering and Technology, 2(3), 1–20. https://doi.org/10.5281/zenodo.20046848

Pereira, A. C. (2026b). Application of magnesium sulfate in in-situ leaching of rare earth elements: Mechanisms, performance and environmental implications. International Journal of Current Science Research and Review, 9(3), 1371–1399. https://doi.org/10.47191/ijcsrr/V9-i3-25

Pereira, A. C. (2026c). Brazil's rare earth elements landscape: From geological endowment to mine-to-magnet integration—Operations, resources, bottlenecks, market prospects, and research gaps. Nexus Science Review, 1(4), 1–59. https://doi.org/10.66104/7tpw1x21

Pereira, A. C. (2026d). Conventional ion-exchange and chelating resins for metal recovery: A critical comparison of selectivity, dynamic performance, regeneration, and process integration. International Journal of Current Science Research and Review, 9(9), 4916–4945. https://doi.org/10.5281/zenodo.22658215

Pereira, A. C. (2026e). Dysprosium under supply constraint: A critical review of demand growth, HREE supply concentration, magnet-efficiency strategies, recycling, and the potential supply–demand gap. Journal International Review of Research Studies, 1(8). https://doi.org/10.66104/0evd3w87

Pereira, A. C. (2026f). Global accidents in solution mining: Causes, mechanisms, consequences and lessons learned. IKR Journal of Engineering and Technology, 2, 35–63. https://doi.org/10.5281/zenodo.19136721

Pereira, A. C. (2026g). Hydrometallurgical recovery of rare earth elements from metallurgical slags (2020–2026): A critical review. International Journal of Current Science Research and Review, 9(4), 1784–1812. https://doi.org/10.47191/ijcsrr/V9-i4-12

Pereira, A. C. (2026h). In situ recovery and in situ leaching of selected critical and strategic metals: A critical review of geological preconditions, reactive transport, process engineering, environmental risk, and scale-up (2015–2026). IKR Journal of Multidisciplinary Studies, 2(5). https://doi.org/10.5281/zenodo.22904358

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Pereira, A. C. (2026i). Mineral beneficiation using attrition scrubbing: Mechanisms, applications and process optimization. IKR Journal of Multidisciplinary Studies, 2, 30–57. https://doi.org/10.5281/zenodo.19372702

Pereira, A. C. (2026j). Percolation, Collection and Recirculation in Heap Leaching: Hydraulic Design, Solution Chemistry Management, and System Reliability – A Critical Review. Journal International Review of Research Studies, 1(09 - September). https://doi.org/10.66104/4p6d0h27

Pereira, A. C. (2026k). Rare Earth Recovery from Weathered Carbonatite Deposits: Mineralogical Constraints, Process Development, and Selective Sulfation Strategies. Nexus Science Review, 1(05 - October), 1-37. https://doi.org/10.66104/wsf0bc19

Pereira, A. C. (2026l). Recovery of rare earth elements from hard disk drives: Technologies, challenges, and circular economy perspectives. IKR Journal of Multidisciplinary Studies, 2(2), 1–25. https://doi.org/10.5281/zenodo.19068704

Pereira, A. C. (2026m). Scale-up in mineral processing: From mechanism preservation to flowsheet-scale transferability—A critical review and the MINESCALE framework. Journal of Advanced Multidisciplinary Studies (JAMS), 1(III), 661–694. https://jamsjournal.org/JAMS/article/view/800

Pereira, A. C. (2026n). Selective thorium separation from rare earth leach solutions: Hydrometallurgical strategies, process limitations, and future perspectives. Journal International Review of Research Studies, 1(5), 1–55. https://doi.org/10.66104/2syq3w92

Pereira, A. C. (2026o). Sulfuric acid regeneration from magnesium sulfate streams: Process chemistry, recovery technologies, and industrial challenges. International Journal of Current Science Research and Review, 9(5), 2797–2832. https://doi.org/10.47191/ijcsrr/V9-i5-54

Pham, V. Q., Vinh, V. D., Ouillon, S., Vu, V. T., Hue, N. T., Ngoc, D. H., Dau, X. T., Belhadj, M., & Jeandel, C. (2025). Rare earth elements and neodymium isotopes in dissolved and particulate phases in the Cam River and Nam Trieu Estuary, north Vietnam. Estuarine, Coastal and Shelf Science, 319, 109248. https://doi.org/10.1016/j.ecss.2025.109248

Phetmany, S., Keohavong, B., Douangdy, B., Bounyasone, X., & Hu, X. (2026). Riverine ecosystem contamination and ecological risk assessment following cyanide leakage from in situ rare earth mining in northern Laos. Earth, 7(3), 96. https://doi.org/10.3390/earth7030096

Qiu, S., Hua, Y., Fan, Z., Long, Q., Zhang, K., Lian, X., Tu, T., Li, L., & Qiu, T. (2025). Theoretical investigation of competitive adsorption of light and heavy rare earth ions on the (001) surface of kaolinite. Molecules, 30(4), 838. https://doi.org/10.3390/molecules30040838

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Qiu, S., Yan, H., Hong, B., Long, Q., Xiao, J., Li, F., Tong, L., Zhou, X., & Qiu, T. (2022). Desorption of REEs from halloysite and illite: A link to the exploitation of ion-adsorption RE ore based on clay species. Minerals, 12(8), 1003. https://doi.org/10.3390/min12081003

Quijada-Maldonado, E., & Romero, J. (2021). Solvent extraction of rare-earth elements with ionic liquids: Toward a selective and sustainable extraction of these valuable elements. Current Opinion in Green and Sustainable Chemistry, 27, 100428. https://doi.org/10.1016/j.cogsc.2020.100428

Rezaei, M., Sanchez-Lecuona, G., & Abdolazimi, O. (2025). A cross-disciplinary review of rare earth elements: Deposit types, mineralogy, machine learning, environmental impact, and recycling. Minerals, 15(7), 720. https://doi.org/10.3390/min15070720

Rodríguez Varela, R., Chagnes, A., & Forsberg, K. (2025). Third-phase formation in rare earth element extraction with D2EHPA: Key factors and impact on liquid membrane extraction performance. Membranes, 15(7), 188. https://doi.org/10.3390/membranes15070188

Rosa, C. A., & Yunita, P. (2026). Trade policy as geoeconomic statecraft: Regulatory positioning in Vietnam's rare earth supply chains. Ilomata International Journal of Social Science, 7(4), 1–12. https://doi.org/10.61194/ijss.v7i4.2799

Russo, S. C., González-Álvarez, I., Cocker, H. A., & McCoy-West, A. J. (2025). The fundamentals of rare earth element ion adsorption clay deposits: A mineral systems approach for exploration. Journal of Geochemical Exploration, 278, 107845. https://doi.org/10.1016/j.gexplo.2025.107845

Rybak, A., Rybak, A., Boncel, S., Kolanowska, A., Jakóbik-Kolon, A., Bok-Badura, J., & Kaszuwara, W. (2024). Modern rare earth imprinted membranes for the recovery of rare earth metal ions from coal fly ash extracts. Materials, 17(13), 3087. https://doi.org/10.3390/ma17133087

Sager, M., & Wiche, O. (2024). Rare earth elements (REE): Origins, dispersion, and environmental implications—A comprehensive review. Environments, 11(2), 24. https://doi.org/10.3390/environments11020024

Saravanan, P., Kannan, R. R., Saravanan, V., Venkatkumar, S., Rajasimman, M., Sagadevan, S., & Baskar, G. (2025). Current status and future directions: Separation of rare earth elements by sorption processes. Journal of Molecular Liquids, 419, 126751. https://doi.org/10.1016/j.molliq.2024.126751

Shalchian, H., Hajizadeh Navakh, M., Birloaga, I., Babakhani, A., & Vegliò, F. (2024). A comparison study on the recovery of REEs from red mud by sulfation roasting–water leaching and citric acid leaching. Minerals, 14(10), 1044. https://doi.org/10.3390/min14101044

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Shi, S., Pan, J., Dong, B., Zhou, W., & Zhou, C. (2023). Bioleaching of rare earth elements: Perspectives from mineral characteristics and microbial species. Minerals, 13(9), 1186. https://doi.org/10.3390/min13091186

Shuai, Z., Zhu, Y., Gao, P., & Han, Y. (2024). Rare earth elements resources and beneficiation: A review. Minerals Engineering, 109011. https://doi.org/10.1016/j.mineng.2024.109011

Sobri, N. A., Mohd Yunus, M. Y. B. M., & Harun, N. (2023). A review of ion adsorption clay as a high potential source of rare earth minerals in Malaysia. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2023.03.513

Souza, C., Ferreira, P. A. P. V. S., & Ladeira, A. C. Q. (2025). Separation of rare earth elements by ion exchange resin: pH effect and the use of fractionation column. Minerals, 15(8), 821. https://doi.org/10.3390/min15080821

Sun, Y., Hu, H., Ngo, X.-D., Kynický, J., Luo, T., Deng, X.-D., & Li, J.-W. (2023). Two episodes of carbonatite-related rare-earth element mineralization in the Nam Xe deposit, northwestern Vietnam: Implications for ore genesis and regional metallogeny. Ore Geology Reviews, 162, 105698. https://doi.org/10.1016/j.oregeorev.2023.105698

Tamayo-Soriano, D. A., Soria-Aguilar, M. de J., Picazo-Rodríguez, N. G., Martínez-Luévanos, A., Carrillo-Pedroza, F. R., Figueroa-López, U., & Valenzuela García, J. L. (2024). Acid leaching of La and Ce from ferrocarbonatite-related REE ores. Minerals, 14(5), 504. https://doi.org/10.3390/min14050504

Tetzner, A. B. G., Farias, C. H. B. de, Freitas, N. P. de, & Campos, A. B. de. (2026). Rare earth elements, sustainability, and ion-adsorption clay: A bibliometric study on global trends and Brazil's prominence. Journal of the Geological Survey of Brazil, 9(1). https://doi.org/10.29396/jgsb.2026.v9.n1.2

Tian, G., Xu, Z., Li, X., Hu, Z., & Zhou, B. (2025). Research progress on the extraction and separation of rare-earth elements from waste phosphors. Minerals, 15(1), 61. https://doi.org/10.3390/min15010061

U.S. Geological Survey. (2024). Mineral commodity summaries 2024. https://doi.org/10.3133/mcs2024

U.S. Geological Survey. (2025). Mineral commodity summaries 2025. https://doi.org/10.3133/mcs2025

U.S. Geological Survey. (2026). Mineral commodity summaries 2026. https://doi.org/10.3133/mcs2026

Vo, P. H. N., Danaee, S., Hai, H. T. N., Huy, L. N., Nguyen, T. A. H., Nguyen, H. T. M., Kuzhiumparambil, U., Kim, M., Nghiem, L. D., & Ralph, P. J. (2024). Biomining for sustainable recovery of rare earth elements from mining waste: A comprehensive

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

review. Science of the Total Environment, 908, 168210. https://doi.org/10.1016/j.scitotenv.2023.168210

Wang, G., Ling, B., Liang, X., Xu, J., Kang, S., Wei, J., Tan, W., Zhu, R., Zhu, J., & He, H. (2024). Transport model of rare earth elements in weathering crusts during electrokinetic mining. Minerals, 14(4), 360. https://doi.org/10.3390/min14040360

Wang, J., Lu, W., Cao, Z., Wu, X., Wang, P., Wang, X., & Liu, W. (2024). New insights into the depressive mechanism of sodium silicate on bastnaesite, parisite, and fluorite: Experimental and DFT study. Minerals, 14(9), 870. https://doi.org/10.3390/min14090870

Wang, L., Li, L., Li, K., & Huang, L. (2024). Influence of clay particle interactions on leaching percolation in ion-adsorption-type rare earth ores. Minerals, 14(2), 140. https://doi.org/10.3390/min14020140

Wang, Q., Qi, T., Liu, Y., Yu, H., Zhang, L., & Zhan, W. (2025). Sulfuric acid leaching of ionic rare earth magnesium salt enrichment and removing aluminum by MgO precipitation. Minerals, 15(2), 189. https://doi.org/10.3390/min15020189

Wang, S., Zhong, C., Shen, C., Wei, Y., He, Q., Chen, J., & Qiu, H. (2025). Selective-crystallization strategy for the separation of rare earth elements: A minireview. Coordination Chemistry Reviews, 537, 216686. https://doi.org/10.1016/j.ccr.2025.216686

Wang, W., Li, E., Li, Z., Zhu, W., & Wang, Y. (2024). Recovery of xenotime and florencite from silicate minerals using a combined technique of magnetic separation and flotation. Minerals, 14(11), 1073. https://doi.org/10.3390/min14111073

Wang, Y., Gao, F., Sun, B., Chen, W., & Nie, Z. (2025). Life cycle assessment for rare earth production from ion-adsorption deposits: A comparative study of magnesium sulfate and ammonium sulfate leaching techniques. Journal of Environmental Management, 385, 125627. https://doi.org/10.1016/j.jenvman.2025.125627

Woods, D. (2025). A Stackelberg model of China's rare earths strategic lead. Journal of Chinese Political Science. https://doi.org/10.1007/s11366-025-09921-w

Wu, X., Feng, J., Zhou, F., Liu, C., & Chi, R. (2024). Optimization of a rare earth and aluminum leaching process from weathered crust elution-deposited rare earth ore with surfactant CTAB. Minerals, 14(3), 321. https://doi.org/10.3390/min14030321

Wu, Z., Chen, Y., Wang, Y., Xu, Y., Lin, Z., Liang, X., & Cheng, H. (2023). Review of rare earth element (REE) adsorption on and desorption from clay minerals: Application to formation and mining of ion-adsorption REE deposits. Ore Geology Reviews, 157, 105446. https://doi.org/10.1016/j.oregeorev.2023.105446

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Xiao, X., Li, G., Dong, S., Qian, L., & Ou, L. (2025). Sources and enrichment mechanisms of rare-earth elements in the Mosuoying granites, Sichuan Province, Southwest China. Minerals, 15(2), 185. https://doi.org/10.3390/min15020185

Xie, M., Zhou, J., Wang, X., Mo, H., Liu, H., Bai, J., Du, X., & Wu, H. (2026). Formation of HREE-enriched ion-adsorption ore from LREE-rich granodiorite: A case study from the Meng Khun deposit, Laos. Mineralium Deposita, 61, 1347–1363. https://doi.org/10.1007/s00126-026-01437-4

Xu, J., Li, J., Charles, V., & Zhao, X. (2024). Evolution of the rare earth trade network: A perspective of dependency and competition. Geoscience Frontiers, 15(3), 101653. https://doi.org/10.1016/j.gsf.2023.101653

Xue, H., Lv, G., Wang, L., & Zhang, T. (2024). Review of rare earth extraction and product preparation technologies and new thinking for clean utilization. Minerals Engineering, 215, 108796. https://doi.org/10.1016/j.mineng.2024.108796

Yang, X., Zhang, Z., Kuang, S., Wei, H., Li, Y., Wu, G., Geng, A., Li, Y., & Liao, W. (2020). Removal of thorium and uranium from leach solutions of ion-adsorption rare earth ores by solvent extraction with Cextrant 230. Hydrometallurgy, 194, 105343. https://doi.org/10.1016/j.hydromet.2020.105343

Ye, Y., Li, C., Zerbo, O. R. V., Yang, X., Sun, W., Xing, Y., Qian, Y., & Yu, C. (2025). Application of multi-source remote sensing and topographic factor integration in the exploration of ion-adsorption type rare earth deposits: A case study from Houaphanh Province, Laos. Minerals, 15(11), 1160. https://doi.org/10.3390/min15111160

You, S., Zhang, D., Liu, H., Tang, M., Pang, X., Wang, Y., & Zhang, Z. (2025). Petrogenesis of Jurassic granite from the Shuitou Pluton in South Jiangxi Province, South China: Implications for ion-adsorption rare earth element enrichment. Minerals, 15(5), 476. https://doi.org/10.3390/min15050476

Zeng, X., Zeng, B., Huang, L., Zhong, L., Li, X., & Huang, W. (2022). Adsorption of Y(III) on the interface of kaolinite-H2O: A DFT study. Minerals, 12(9), 1128. https://doi.org/10.3390/min12091128

Zhang, B., Niu, H., Zhang, L., Zhang, B., Zhu, X., Gao, R., Yang, Y., & Zou, Y. (2025). Petrographic, geochemical, and geochronological characteristics of the granite in Yunnan and its constraints on ion-adsorption rare earth element mineralization. Minerals, 15(8), 872. https://doi.org/10.3390/min15080872

Zhang, L., Ji, H., Wang, S., Luo, G., Liu, X., Wei, X., Nguyen, Q. D., & Nguyen, D. T. (2020). Geochemical implications of rare earth elements in terra rossa in tropical karst area: A case study in northern Vietnam. Applied Sciences, 10(3), 858. https://doi.org/10.3390/app10030858

Nexus Science Review
INTERNATIONAL JOURNAL OF INTERDISCIPLINARY RESEARCH

Received: 21/09/2026 - **Accepted:** 19/10/2026
Vol: 01.05
DOI: 10.66104/4gnqn270
Pages: 1-35

Zhang, X., Gao, Z., Rao, Y., Shi, L., & Xu, W. (2023). Evolutionary law of pore structure of ion-adsorbed rare earth ore leaching process. Minerals, 13(3), 322. https://doi.org/10.3390/min13030322

Zhang, Z., Yang, J., Guo, W., Jiang, L., Chen, W., Liu, D., Wu, H., & Chi, R. (2024). Analysis and prediction of the leaching process of ionic rare earth: A data mining study with scarce data. Minerals, 14(6), 596. https://doi.org/10.3390/min14060596

Zhao, C., Wang, J., Yang, B., Liu, Y., & Qiu, G. (2024). Selective separation of rare earth ions from mine wastewater using synthetic hematite nanoparticles from natural pyrite. Minerals, 14(5), 464. https://doi.org/10.3390/min14050464

Zhao, X. (2025). Navigating the US–China rivalry: ASEAN's position on critical mineral resources. Pacific Focus, 40(3), 452–489. https://doi.org/10.1111/pafo.70006

Zhiltsov, S. S., & Hoang, V. T. (2025). Vietnam's policy in the field of rare earth metals. The Russian Journal of Vietnamese Studies, 9(4), 32–46. https://doi.org/10.54631/VS.2025.94-639878

Zhou, L., Yu, H., Kang, S., Sun, G., Deng, Y., Wang, X., Zhao, H., & Xu, J. (2024). Effect of fine particle content on solution flow and mass transfer of ion-adsorption-type rare earth ores. Minerals, 14(9), 879. https://doi.org/10.3390/min14090879