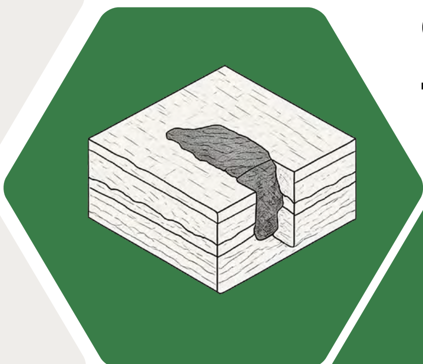
Uranium Investor Foundation Series

A structured set of guides that lay out the fundamental elements of the uranium industry and prepare readers for deeper market interpretation.



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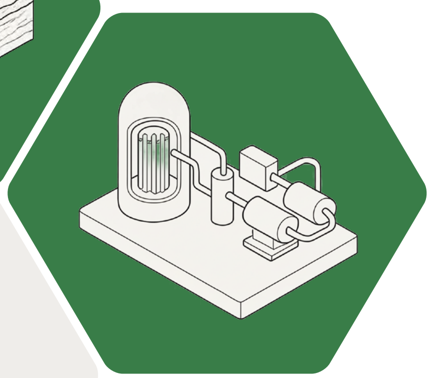
The Nature of Uranium



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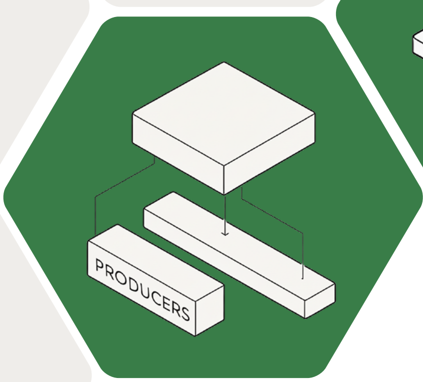
Why Uranium Supply Rarely Arrives on Time



Guide IV:
The Structure of the Uranium Sector

Chris Frostad
Uranium Market Commentator and CEO, Purepoint Uranium Group Inc.
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Author: Chris Frostad
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How to Read This Series

These guides are meant to be read as a sequence. Each one adds a layer of understanding that the next builds on, without repeating what came before. Together, they form a framework for thinking about uranium markets rather than a set of conclusions to be taken one at a time.

Each guide looks at a different structural aspect of the uranium sector. The series moves from the nature of uranium itself, to how reactors actually consume fuel, to why supply so often arrives later than expected, and finally to how the sector is organized and how material flows through it in practice.

No single guide is intended to stand on its own. The ideas are designed to connect, and some of their implications only become clear once the full structure is in place. Readers will get the most value by moving through the series in order, allowing each piece to inform the next.

These guides are not forecasts, price targets, or investment recommendations. Their purpose is to clarify constraints, sequencing, and incentives so that market data and commentary can be interpreted with better context.

The aim throughout is not to introduce more information, but to sharpen how existing information is read. By the end of the series, readers should have a clearer sense of how uranium markets actually behave, and why they often look calm on the surface even when underlying conditions are changing.

TABLE OF CONTENT

GUIDE 1 — The Nature of Uranium

Uranium behaves unlike any other mined commodity, and its physical and geological traits are the root cause of slow supply growth, concentrated mining districts, and persistent market tightness.

1. What This Guide Covers

This Guide explains the fundamental characteristics of uranium as a material — how it forms, how it behaves scientifically, how those behaviours shape the way uranium deposits appear, how they can be mined, and why supply remains slow and complex. The focus is not on mining methods or pricing. It is on the underlying attributes of uranium that make this sector fundamentally different from copper, gold, or any other resource industry.

These traits are the foundation of every supply constraint investors encounter later: why high grades tend to cluster in narrow geological corridors, why production curves flatten rather than rise smoothly, and why bringing new supply to market is more complicated than simply increasing exploration budgets.

2. Why This Matters for Investors

Investors often encounter the visible symptoms of uranium's supply tightness — slow restarts, complex permitting, thin spot markets — without understanding the deeper causes. Those causes sit in the material itself. Uranium's behaviour in the Earth's crust creates uranium districts that are rare, difficult to find, and even harder to replicate. Its chemical properties create milling and processing challenges that lengthen development timelines. Its radioactive decay and oxidation states influence the way it moves underground and how it must be handled at surface.

Different regions face different constraints, but the outcome is the same: uranium supply from every deposit style grows slowly, responds weakly to price, and remains vulnerable to disruption. Even when prices rise, miners cannot simply "turn on" new production the way bulk metals can. Understanding the material itself helps investors understand why supply repeatedly falls behind demand, why forecasts consistently overestimate future production, and why the industry cycles are so sharp once tightness becomes visible.

For investors, the behaviour of uranium is not an academic issue — it is the root of the investment thesis.

3. Uranium's Key Geological, Chemical, and Physical Traits (and why they matter to the supply side)

Uranium stands out because of three defining categories of behaviour. These traits shape not only where uranium deposits occur but also how they are mined, how long projects take to develop, and why global supply is chronically concentrated in a few regions.

Uranium deposits range from extremely high-grade hard rock systems to vast low grade sedimentary or roll front deposits. Grade alone does not determine economic viability. Geometry, depth, host rock conditions, groundwater behaviour, and processing simplicity are equally influential. This is why lower grade regions such as Kazakhstan, the USA, and Niger can support large scale production even though their ore grades are far below those of Canada.

A. Geological Behaviour: Uranium Moves, Concentrates, and Re-Concentrates

Uranium is unusually mobile in the Earth's crust. It dissolves easily in oxygen-rich fluids, travels long distances, and then precipitates rapidly when conditions change. This "mobilize, transport, trap" cycle is what creates extremely high-grade deposits like those in Saskatchewan, Canada. It is also why so many parts of the world contain modest uranium showings but very few contain economic discoveries.

For Investors:
- High-grade uranium districts are rare, formed only where geological conditions aligned perfectly.
- New discoveries tend to cluster around existing districts rather than emerging in new regions.
- Exploration success is inherently uneven — the world does not have many undiscovered Athabasca Basins.

B. Chemical Behaviour: Multiple Oxidation States Create Milling Complexity

Uranium changes behaviour depending on its oxidation state (U^{4+}, U^{6+}). In oxidizing conditions, it becomes mobile; in reducing environments, it fixes in place. These chemical swings also dictate how easily uranium can be extracted during processing. Ores with mixed oxidation states often require multi-stage leach circuits or specialized reagents. This complexity adds cost, extends development timelines, and creates operational risk.

For Investors:
- Processing complexity reduces the number of deposits that can be profitably mined.
- Many global deposits remain undeveloped not because they are small, but because their chemistry is difficult.
- Projects with predictable mineralogy command premium valuations because they offer cleaner, more reliable flowsheets.

C. Physical Behaviour: Radioactivity, Density, and Heat Drive Operational Constraints

Uranium's density, radioactivity, and thermal output influence both mining methods and surface operations. High-grade ore generates meaningful heat and radiation, which restricts how miners can handle, move, and store it. This is why mines in high-grade districts rely on specialized underground designs, freeze walls, headframe cooling systems, and careful ore-handling logistics. These requirements slow down production rates and cap how quickly mines can scale.

For Investors:
- High-grade ore is valuable but comes with engineering limits that slow output.
- Production curves for uranium mines rise gradually, rarely reaching nameplate capacity quickly.
- Technical constraints create natural bottlenecks that keep supply from expanding smoothly.

The Athabasca Basin in northern Saskatchewan illustrates how uranium can be repeatedly mobilized by oxidized fluids and then sharply re-concentrated along basement faults, creating exceptionally high-grade deposits in very limited corridors.

4. Why Uranium Forms Concentrated Uranium Districts

Uranium is found in many places around the world, yet true economic deposits occur in only a small number of geological settings. Even within those settings, uranium ore accumulates in clusters rather than spreading evenly across a basin. This concentration is not coincidence. It is the product of a very particular sequence of geological conditions that must line up with precision. When they do, the result can be exceptional grade or exceptional size. When they do not, the result is often low-grade mineralization that will never support a mine.

Understanding this pattern is essential because it explains why global supply relies so heavily on a handful of regions. It also explains why new discoveries tend to appear close to existing mines rather than in unexplored jurisdictions. The distribution of uranium is controlled by natural processes that reward certain geologies and exclude most others.

A. Uranium Is Abundant but Not Usually Economic

Uranium is common in the Earths crust. It occurs in granites, sediments, volcanic rocks, and groundwater. Yet the vast majority of this uranium is measured in parts per million. These levels are far below what is required for profitable extraction. The presence of uranium alone is meaningless for investors. What matters is whether the geological system has concentrated that uranium into zones where it can be mined and processed at scale.

Although high-grade districts supply a significant share of global uranium, large regional production also comes from lower grade systems such as sandstone hosted roll front deposits in Central Asia, Africa, and the USA. These deposits rely on access to favourable geometry and chemistry rather than grade. They demonstrate that high-grade is not a requirement for economic uranium mining, but one of several viable geological pathways to supply.

For Investors:

- Most uranium showings do not have the concentration needed for development.
- Discovery is not about finding uranium but about finding the right geological conditions for concentration.
- This is why exploration success rates are low compared with many other commodities.

B. The Geological Conditions That Create High-Grade Zones Are Rare

To form a high-grade uranium deposit, several conditions must occur together. These include a large source of uranium, a long-lived fluid system capable of transporting it, and a trap that causes uranium to fall out of solution. Even slight differences in temperature, chemistry, structure, or timing can determine whether a region hosts world class deposits or none at all.

These precise requirements create natural clustering. If conditions were right in one part of a basin, they were often right nearby. If conditions failed in one place, they likely failed in the surrounding area as well.

For Investors:

- Grade clusters are predictable once the controlling geology is understood.
- The best indicator of future discovery is proximity to existing discoveries.
- Districts with repeated discovery success tend to keep delivering new deposits.

C. Uranium Moves Through the Crust and Accumulates Along Structural Corridors

Uranium is highly mobile under oxidizing conditions. It dissolves, moves with groundwater, and travels long distances. It accumulates only when those fluids encounter a reducing environment that forces uranium out of solution. These changes often occur along structural corridors where faults, shears, and permeable zones intersect.

Where these conditions align repeatedly, uranium can stack in narrow bands, often directly above or beside major structural breaks. This is why high-grade deposits are not spread across entire basins but are located along distinct geological trends.

For Investors:

- Structural trends define the real footprint of a district.
- Exploration outside these trends carries far lower probability of success.
- Companies with land packages that cover these corridors have far better discovery potential.

D. Once a District Proves Its Potential, It Often Delivers Multiple Deposits

Uranium deposits rarely form in isolation. Where one deposit is present, others often exist nearby because the same geological system influenced the entire region. This is true across the world and across deposit styles. Districts with a history of high-grade production often continue to produce discoveries decades after the first mine.

This pattern supports a key point for investors. The most prospective exploration ground is not the untouched frontier. It is the ground within proven districts where the geological ingredients are already confirmed.

For Investors:

- Mining camps are the natural engines for repeat discoveries.
- District-scale holdings matter more in uranium than in most metals.
- New regional entrants face an uphill battle without demonstrated district geology.

E. Why High-Grade Regions Dominate Global Supply

The geological barriers that create grade also restrict global production. There are very few places where all the necessary conditions exist. As a result, a small number of jurisdictions provide most of the uranium that the world relies on. These regions are difficult to replace because the conditions that formed them cannot be recreated through exploration effort alone. They are geological accidents that occurred over millions of years.

This concentration means global supply is inherently fragile. If one major district underperforms, there are few alternative sources capable of filling the gap. Price signals alone cannot change this.

For Investors:

- Global production is concentrated because the geology demands it.
- Supply risk is higher in uranium than in most metals because substitution between districts is limited.
- The rarity of high-grade regions is one of the drivers of structural tightness.

Across global uranium provinces, economic deposits consistently occur in clusters within proven districts, while vast surrounding areas with similar rock types contain only sub-economic mineralization.

5. How Uranium's Chemistry Creates Operational Complexity

Uranium's chemical behaviour has more influence on mine development than most investors realize. The way uranium bonds, dissolves, oxidizes, and concentrates determines not only whether a deposit can be mined, but also how complex the processing plant must be and how predictable the operation will become over time. Two deposits with identical grades can have very different economics simply because their chemistry responds differently to leaching, oxidation, or impurities in the host rock.

Understanding these chemical constraints explains why the industry has a limited number of operating centres, why restarts often take longer than expected, and why the cost of building a new mine varies so widely. It also explains why many deposits that appear attractive in resource statements never advance to production.

A. Uranium Changes Form Easily, and Each Form Requires Different Processing

Uranium switches between oxidation states as it moves through the crust. In its reduced form it is stable and immobile. In its oxidized form it becomes highly soluble. These two states require different processing approaches, and many deposits contain both within the same ore body. The mill must therefore be designed to handle ore that behaves unpredictably as chemistry shifts from zone to zone.

Ore that contains both forms generates variable recovery rates and may require adjustments to reagents, temperature, or retention time. This variability increases technical risk and raises operational costs.

For Investors:

- Deposits with mixed oxidation states rarely achieve smooth, predictable recoveries.
- Cash flow models that assume constant recovery can underestimate risk.
- Deposits with simple, consistent chemistry carry premium valuation because their processing is more reliable.

B. Uranium Often Occurs with Elements That Interfere with Recovery

Many uranium deposits include impurities that consume reagents or contaminate solutions. Clays, carbonaceous material, and certain sulphides can neutralize acid or bind with uranium in ways that reduce extraction efficiency. In other cases, the host rock contains minerals that generate fines, causing filtration, settling, and pumping issues.

These complications often require pre-treatment steps or specialized leaching conditions. Each step adds cost, engineering complexity, and risk of downtime.

For Investors:

- Metallurgical complexity is often the reason a promising deposit stalls before development.
- Additional mill circuits increase capital cost and raise the break-even price required for project approval.
- Deposits with clean mineralogy often outperform their reserve models because the chemistry is predictable.

C. Uranium's Solubility Creates Environmental and Water Management Constraints

When uranium becomes mobile in oxidizing conditions, it can migrate with groundwater. This natural behaviour means that any disturbance to the ore zone must control how water interacts with both the ore and the surrounding rocks. Leaching, neutralization, and water treatment circuits must be designed to prevent unwanted dissolution of uranium outside intended zones.

This requirement introduces monitoring, containment, and treatment steps that lengthen development timelines and add technical oversight to regular operations. Even when executed well, these measures slow the pace at which production can scale.

For Investors:

- Water management drives a significant portion of operating and capital costs.
- Regulatory scrutiny increases when uranium is easily mobilized, extending timelines.
- Projects that naturally limit interaction with groundwater offer smoother paths to development.

D. Processing Requirements Limit the Range of Viable Deposits

Most commodities can be mined profitably across a wide range of grades and mineral settings. Uranium is different. Its chemistry dictates which deposits are feasible. Many known deposits are technically mineable but economically impractical because they require complex reagent systems or produce low recoveries.

This is why global uranium supply remains concentrated. Even when exploration identifies new resources, only a portion of them can move through the chemical hurdles of milling and treatment at a cost that supports long-term operation.

For Investors:

- A large resource does not guarantee a future mine if the chemistry is unfavourable.
- Global supply is constrained by chemistry as much as geology.
- Chemical simplicity is often a stronger indicator of future development than headline grade.

E. Chemistry Slows the Ramp Up of New Mines

Even after construction, uranium mills require extended commissioning. Processing circuits must be optimized slowly as ore from different parts of the deposit enters the mill. This staged tuning period can take months or years. Production rarely reaches nameplate capacity quickly, and early guidance often reflects this reality.

This slow optimization is not operational underperformance. It is the natural result of a material that behaves differently as conditions change.

For Investors:

- Production guidance almost always trails nameplate for reasons rooted in chemistry, not execution.
- Ramp up delays are common and should be expected rather than viewed as negative surprises.
- Long-term reliability matters more than early output.

Many uranium deposits worldwide require tailored processing circuits because small changes in oxidation state or host rock chemistry can materially affect recovery from one part of the ore body to another.

6. The Natural Supply Bottlenecks Built Into the Material

Even before engineering, permitting, financing, or geopolitics come into play, uranium faces built in supply constraints rooted directly in how the material forms and behaves. These are not temporary obstacles. They are natural limits that shape the entire supply side of the market. They determine which deposits can become mines, how fast those mines can ramp, and how much sustained production they can deliver.

These bottlenecks explain why rising prices do not lead to an immediate supply response, why forecasts often overestimate future output, and why the uranium market experiences long periods of tightness even when development capital becomes available.

A. Only a Small Fraction of Known Deposits Are Actually Mineable

Uranium is widely distributed, but most known deposits cannot support commercial production. Many are too deep, have unsuitable host rocks, or present chemical or geological conditions that make extraction impractical. Grade may be a limit in some systems, while in others geometry, permeability, or water chemistry is the defining constraint.

Unlike bulk commodities, where large low-grade systems can still produce at scale, uranium requires a narrow combination of grade, thickness, chemistry, and geometry. Without all of these elements in place, a deposit remains a geological curiosity rather than a viable mine.

For Investors:

- Resource size alone is not a predictor of future supply.
- Global inventories of undeveloped uranium are large on paper but limited in real availability.
- Only a small portion of known resources has the physical attributes needed for long-term production.

B. High-Grade Deposits Are Often Physically Constrained

Exceptional grade is a signature advantage of certain uranium districts, but it also creates natural limits. High-grade ore generates meaningful heat and radiation. These factors restrict the speed at which ore can be handled, the size of working areas underground, and the methods used for development.

Cooling, shielding, ground freezing, and specialized material handling systems are often required. These systems keep workers safe but also impose physical caps on production rates. Even a world class deposit cannot simply produce faster because engineering limits define the pace of extraction.

For Investors:

- High-grade does not guarantee high throughput.
- Production rates are capped by physics, not by willingness to invest.
- Supply from the best deposits grows slowly and predictably, rarely exceeding design limits.

C. Ore Moves in Narrow, Structurally Controlled Zones

Uranium deposits rarely form as large, uniform bodies. They often appear as narrow lenses or pods along structural breaks. This geometry restricts mining methods and creates sequencing limits. Only certain segments of the ore body can be accessed at one time. As mining moves through these zones, production rates fluctuate naturally.

This is very different from bulk metal deposits where wide open mining panels deliver steady tonnage. Uranium's geometry forces a stop and start rhythm, even in technically well managed operations.

For Investors:

- Production curves for uranium mines seldom resemble smooth growth profiles.
- Narrow ore bodies introduce natural pauses and declines as zones are mined out.
- Structural geometry creates real limits on sustained production.

D. Chemistry Constrains Processing Capacity

Ore cannot be processed faster than the circuit can handle its chemistry. Complex ores consume reagents unevenly, generate fines that slow filtration, or require multi stage leach cycles. Plants must be tuned carefully to avoid issues with recovery, heat balance, or tailings management.

This chemical sensitivity places upper limits on how much ore a mill can process safely and efficiently. Increasing throughput without detailed testing often causes operational instability rather than increased output.

For Investors:

- Incremental expansions are rarely simple or quick.
- Processing limits often become the controlling bottleneck for long-term production.
- Many projects run below nameplate to maintain stable recoveries.

E. Groundwater and Environmental Controls Slow Development

Uranium interacts readily with groundwater. This natural mobility requires rigorous water control, containment, and treatment systems. These systems take time to design, permit, and commission. Once operating, they dictate the pace of mining. Water inflow, pressure, and chemistry influence how quickly development headings can advance and how safely ore can be extracted.

This is not simply regulatory overhead. It reflects the nature of the material and the need to manage its behaviour underground and at surface.

For Investors:

- Water management is often the slowest part of project ramp up.
- Development schedules stretch naturally because of hydrogeological constraints.
- Even well operated mines experience periodic slowdowns due to water inflow and treatment limits.

F. These Bottlenecks Limit the Industry's Ability to Respond to Price

The combined effect of these constraints is a supply base that cannot accelerate quickly. Even when prices rise sharply, most projects remain limited by geology, chemistry, geometry, or environmental conditions that money cannot resolve on short timelines.

This is why uranium supply behaves differently from other commodities. It is not simply cyclical inertia. It is the natural outcome of a material whose properties impose physical and chemical limits on every stage of production.

For Investors:

- Supply tightness persists even in favourable markets.
- Price signals influence capital but do not overcome natural bottlenecks.

- These constraints explain much of uranium's price asymmetry during tight cycles.

G. Different Deposit Types Create Different Bottlenecks

Not all uranium deposits face the same constraints. High-grade hard rock deposits are limited by heat, radiation, narrow ore zones, and complex underground development. In contrast, large low-grade roll front deposits are constrained by groundwater chemistry, permeability, and the ability to sustain stable in situ recovery patterns. Open pit deposits face strip ratios and large material handling requirements. Each deposit style has its own physical and chemical limits, and no style can simply scale production rapidly in response to price. Investors should evaluate bottlenecks based on deposit type, not grade alone.

For Investors:

- Kazakhstan style ISR operations face permeability and well field limits.
- USA ISR deposits require clean groundwater chemistry and favourable sediments.
- African and Australian hard rock deposits depend on geometry, depth, and reagent consumption.
- Each deposit style scales differently and fails differently.
- Understanding which bottlenecks apply to which deposit style helps investors compare projects realistically, rather than relying on grade alone as the main indicator of future supply potential.

Even world-class uranium deposits, such as Canada's Athabasca Basin, are constrained by physics, chemistry, and geometry, which cap extraction rates and prevent production from accelerating quickly in response to higher prices.

7. Why Uranium Production Curves Are Non-Linear

Uranium mines almost never follow the smooth ramp up and steady state profiles common in other commodities. Their production curves bend, pause, flatten, and step in irregular intervals. These patterns are not operational flaws or management missteps. They reflect the natural behaviour of uranium deposits and the technical constraints that define how they can be mined.

ISR operations do not use a conventional mill, yet they also face chemistry driven constraints. Variations in groundwater chemistry, permeability, or reagent consumption can reduce recovery rates or shorten well field life, creating bottlenecks just as meaningful as those seen in hard rock processing.

Understanding these curves is central to understanding supply. They show why production frequently underperforms expectations, why supply forecasts tend to overshoot, and why the market fails to respond quickly even when prices rise.

A. Slow Ramps Are Built into the Material

New uranium mines require extended commissioning periods. The mill must adjust to ore that varies in oxidation state, impurity levels, and mineral association. As these zones enter production, recoveries shift and circuits must be tuned gradually.

This creates a slow initial ramp, often lasting months or years. While bulk metals can reach steady state quickly, uranium rarely does.

For Investors:

- Early guidance is usually conservative for good reason.
- Production does not scale simply by adding capital.
- Slow ramps extend tight supply conditions.

B. Production Peaks Are Controlled by Geometry and Chemistry

Even mature uranium mines rarely reach a stable plateau. Narrow ore lenses, heat output, ground conditions, water inflow, and chemical variability all limit the pace of extraction. These constraints cause natural oscillations. As development moves from one zone into another, throughput and grades rise and fall.

This unpredictability is structural. It reflects the true form of uranium ore bodies.

For Investors:

- Expect variability even in well established operations.
- Year to year guidance must be interpreted in the context of deposit shape and chemistry.
- Non-linear production limits the industry's ability to create sustained surpluses.

C. Declines Come Earlier and More Abruptly Than in Other Commodities

Uranium mines often reach peak output earlier in their life and decline sooner than expected. Once the primary ore zones are mined, the remaining material tends to be more complex, thinner, or lower grade. Unlike bulk metals, where lower grade zones still provide large tonnage, uranium deposits often narrow sharply as they progress outward.

This leads to production declines that are more abrupt and difficult to offset.

For Investors:

- Replacement supply must be secured earlier than investors might assume.
- Declining production is a predictable feature of uranium mining.
- These natural declines tighten the long-term supply picture.

D. Interruptions Are More Common Because the System Has Little Slack

Any mine can experience interruptions, but uranium operations are more sensitive to geological and chemical shifts. Minor changes in groundwater inflow, reagent availability, or host rock behaviour can create pauses that would not materially affect other commodities.

Because global supply is concentrated and the system is already thin, these pauses matter. They remove meaningful tonnes from the market and often occur at the same time that demand continues to rise.

For Investors:

- Uranium mines have less buffer against small disruptions.
- Market tightness is tied directly to the fragility of the production base.
- Non-linear output reinforces the value of long-term contracting.

8. Summary and Investor Takeaways

Uranium behaves differently from every other major commodity, and these differences shape the structure of the entire market. The material moves through the crust in ways that produce rare, concentrated, uranium districts. Its chemistry creates processing challenges that limit the number of feasible deposits. Its physical properties cap the pace of extraction. Its geometry and environmental interaction restrict production growth and introduce natural variability.

These constraints apply across all deposit styles. Whether the ore is exceptionally high-grade hard rock or broad low grade roll front, the material itself imposes limits on how quickly supply can grow and how reliably operations can deliver sustained production.

These characteristics explain why uranium supply grows slowly, why production curves are uneven, and why the industry cannot respond quickly to higher prices. They also explain why forecasts often overestimate future output. The gap between theoretical capability and real production is rooted in the material itself.

For Investors:

- Uranium's nature creates structural tightness that price alone cannot fix.
- Supply expands slowly even in favourable market conditions.
- High-grade does not guarantee high throughput.
- The most important risk in uranium investing is not demand, but the fragility of supply.
- Understanding the material prepares investors to evaluate deposits, jurisdictions, and companies with clearer perspective.

9. Connecting Supply to Demand

This Guide focused on the material itself. It showed that uranium is rare in mineable form, complex to process, and slow to bring to market. These characteristics define the limits of supply. The next step is understanding the other side of the equation: **how uranium is consumed by nuclear reactors and why that demand is so stable and predictable.**

Guide 2 will explain how the global reactor fleet uses uranium, how reload cycles work, how enrichment influences annual requirements, and why demand behaves with far less volatility than supply. It also introduces the growing role of new reactor technologies and how they may influence the long-term balance.

Together, these two Guides form the foundation for understanding why the uranium market tightens in multi year cycles and why those cycles matter for investment timing.