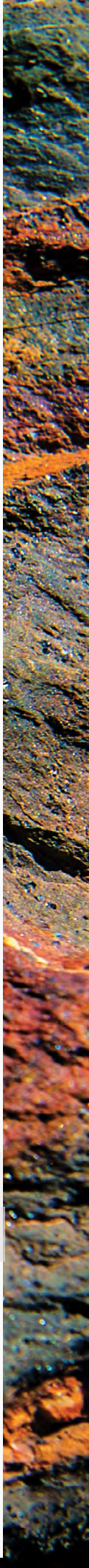
SEEQUENT

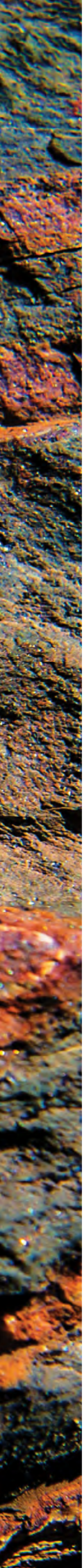
WHITE PAPER

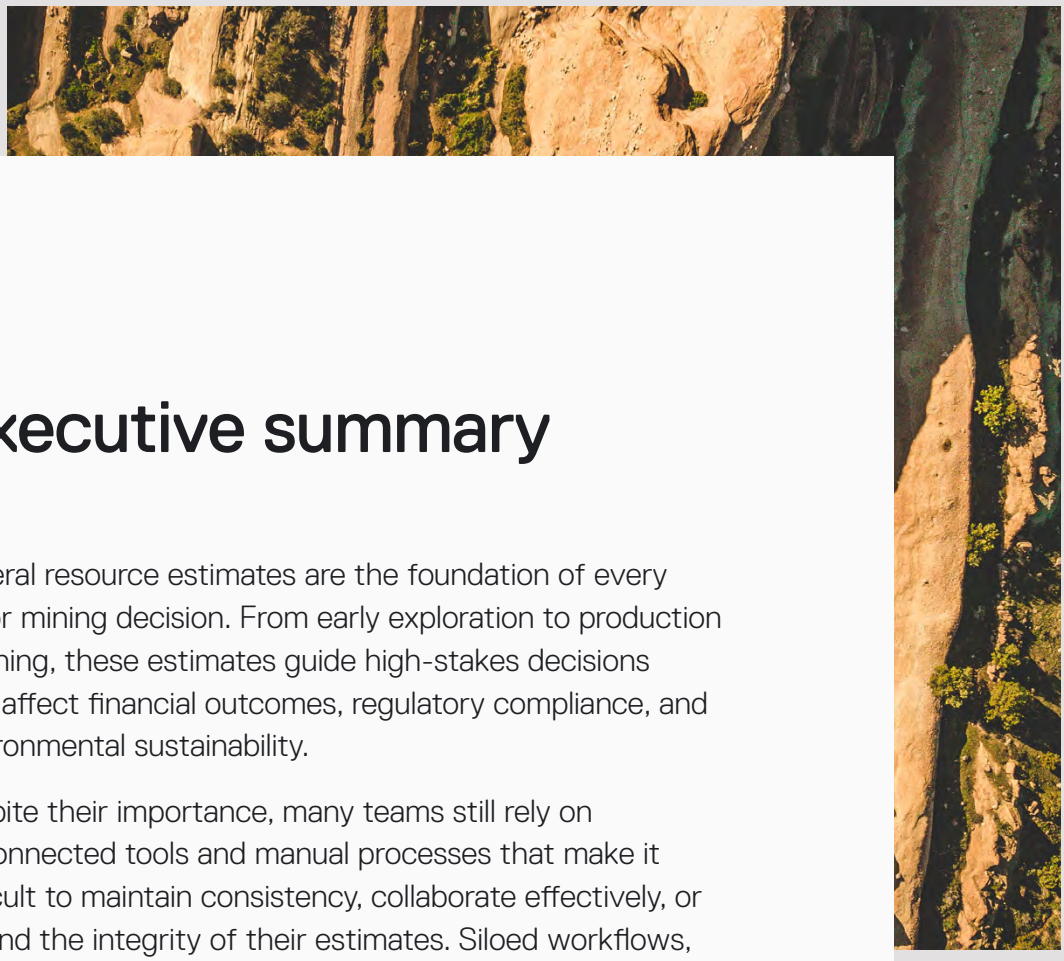
REDUCING RESOURCE RISK WITH DEFENSIBLE ESTIMATES

How Seequent supports transparent, auditable, and connected modelling and estimation across the full mining lifecycle



Seequent, The Bentley Subsurface Company





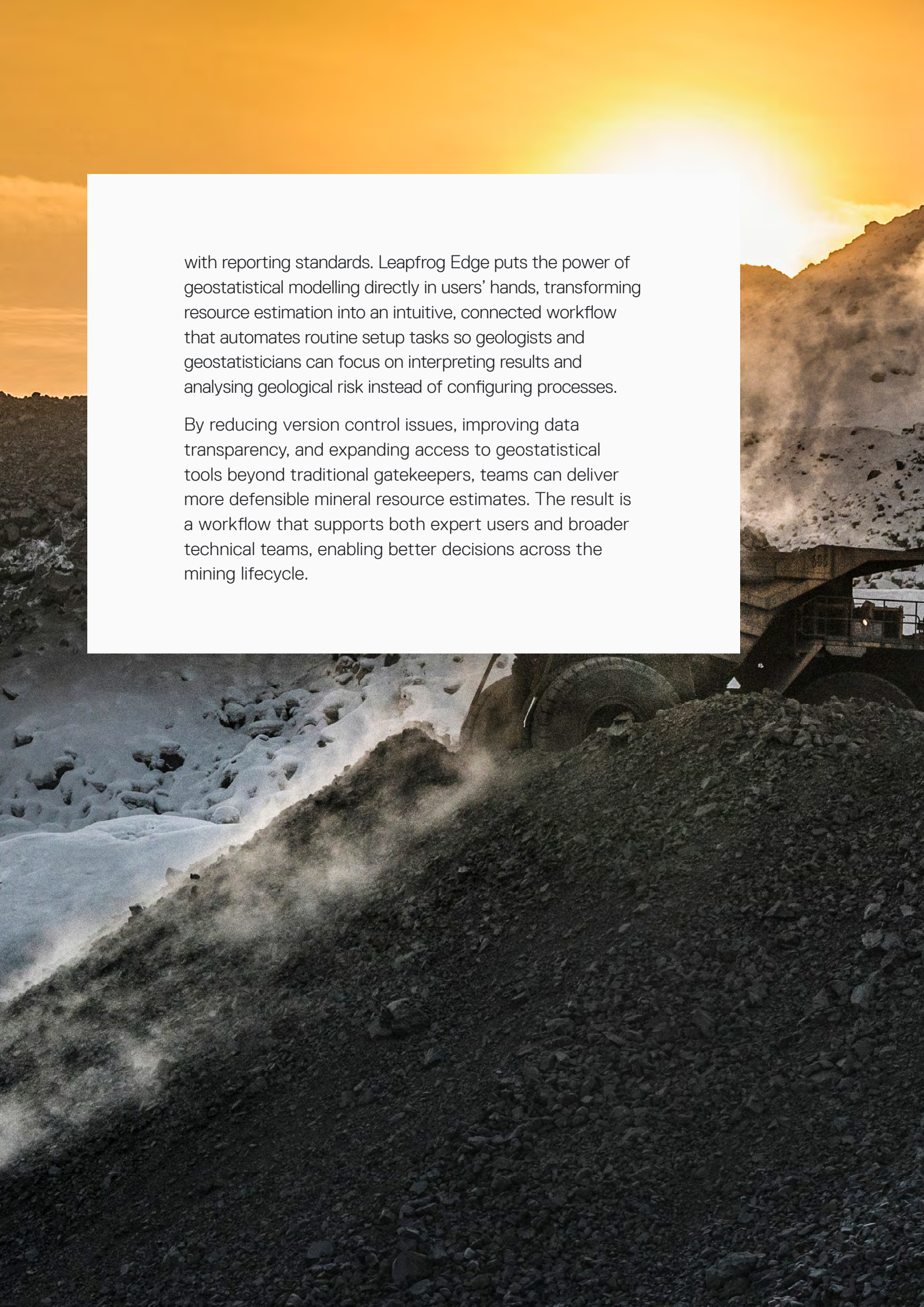
Executive summary

Mineral resource estimates are the foundation of every major mining decision. From early exploration to production planning, these estimates guide high-stakes decisions that affect financial outcomes, regulatory compliance, and environmental sustainability.

Despite their importance, many teams still rely on disconnected tools and manual processes that make it difficult to maintain consistency, collaborate effectively, or defend the integrity of their estimates. Siloed workflows, coding dependencies, and versioning issues introduce delays, uncertainty, and risk.

This white paper explores the technical and operational challenges of traditional mineral resource estimation and introduces a modern, connected alternative.

Seequent's workflow—powered by Leapfrog Geo and its Edge extension—integrates geological modelling and resource estimation into a single, visual, audit-ready environment. Teams can iterate quickly, track every parameter change automatically, validate assumptions visually, and ensure models are transparent and aligned



with reporting standards. Leapfrog Edge puts the power of geostatistical modelling directly in users' hands, transforming resource estimation into an intuitive, connected workflow that automates routine setup tasks so geologists and geostatisticians can focus on interpreting results and analysing geological risk instead of configuring processes.

By reducing version control issues, improving data transparency, and expanding access to geostatistical tools beyond traditional gatekeepers, teams can deliver more defensible mineral resource estimates. The result is a workflow that supports both expert users and broader technical teams, enabling better decisions across the mining lifecycle.

Why resource estimation matters more than ever

Few mining decisions carry more weight than those informed by mineral resource estimates. These estimates determine the commercial viability of a deposit, guide long-term mine planning, influence investment, and underpin technical reporting. Ultimately, they define the potential value of a mining project.

But while the value of mineral resource estimation (MRE) is undisputed, the pressures surrounding its defensibility have grown. Geologists and geostatisticians today face rising expectations from regulators, investors, and ESG stakeholders. Public reporting frameworks like NI 43-101 and the JORC Code now demand not only accurate estimates but also transparent methodologies and auditable workflows.

At the same time, resource complexity is increasing. Teams must model deposits across multiple commodities and domains, often with limited data and tight deadlines. Mistakes carry consequences that ripple across the business, from overpromised reserves to underreported risks.

In this high-stakes environment, producing a resource estimate isn't just a technical task. It's a matter of risk management. The demand is clear: faster workflows, fewer handoffs, and greater confidence in every number reported.

What Bre-X taught the industry about the importance of transparency in MRE

One of the most well-known examples of misreported resource estimates occurred in the Bre-X scandal of the 1990s, where exaggerated gold findings led to massive share price inflation and one of the biggest mining frauds in history.

Bre-X began gold exploration in Indonesia in 1993. Its reported estimates climbed from 30 million to 70 million ounces of gold, pushing its share price from under $1 CAD to a peak of $281 CAD. In March 1997, the scam collapsed when due diligence by Freeport-McMoRan revealed negligible gold content, and Bre-X's exploration manager reportedly died in a helicopter fall. The company's delisting wiped out billions in investor value, including losses to major Canadian pension funds.

As a result of this scandal, investors and regulators expect transparency and defensibility at every step.

CHAPTER 2

Where traditional workflows fall short

For many resource teams, the process of generating mineral resource estimates still relies on a patchwork of tools and workarounds—each designed for a different stage of the workflow, but rarely built to work together.

Geological modelling is handled in one system, estimation in another, and validation often happens offline or with custom scripts. These disconnected workflows introduce inefficiencies, inconsistencies, and the unnecessary risk of version control issues, data transfer errors, or inconsistent assumptions.

One of the most persistent challenges is the reliance on manual steps or scripted processes. While some users are comfortable coding, it often creates bottlenecks, breaks auditability, and limits access to those with niche technical expertise.

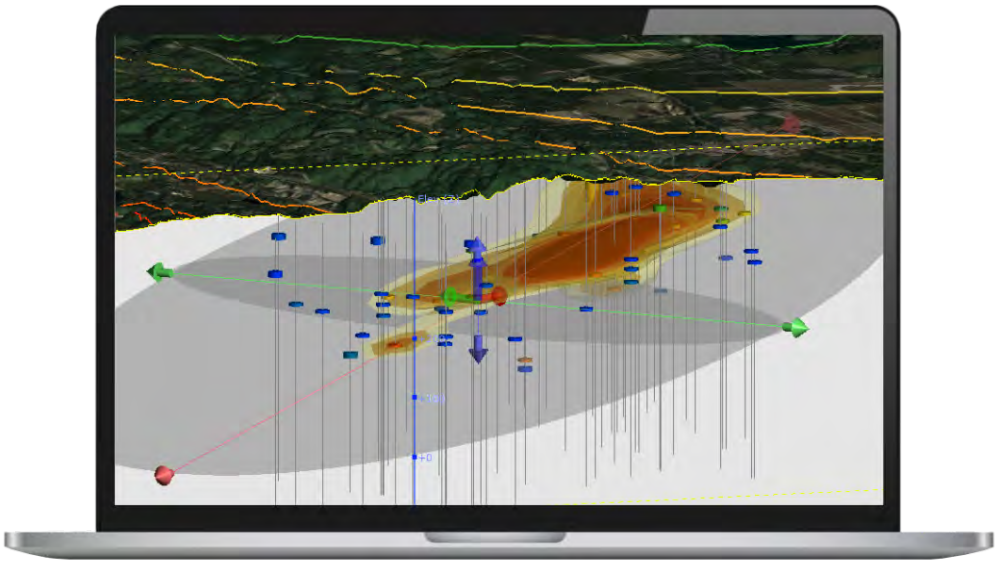
When workflows are custom-coded or poorly documented, they become harder to audit, replicate, or transfer across teams, especially in time-sensitive or high-stakes environments.

Version control is another major friction point. Without a unified environment, teams struggle to manage multiple iterations of models and datasets, leading to confusion about which version is the most current or valid. These inconsistencies can erode trust in the final estimate and complicate regulatory reporting.

Perhaps most critically, traditional workflows limit visibility across teams. When geological models and resource estimates are developed in silos, collaboration is stifled.

Key context can be lost between handoffs, and opportunities for shared insight between other key stakeholders are missed.

The result is that too much time is spent implementing workflows, and not enough time is spent analysing, iterating, or improving them. Today, speed, transparency, and defensibility are key. Traditional approaches simply can no longer keep pace. The question many resource geologists and geostatisticians are asking themselves is: are the workflows being used above the surface impacting our ability to truly and deeply understand what's below the surface?



How Eldorado Gold connects workflows and teams and accelerates MRE

With teams and stakeholders operating across multiple time zones, Eldorado Gold, a global mid-tier producer, needed a way to maintain up-to-date models and enable real-time collaboration from headquarters in Vancouver.

The team adopted Seequent's Leapfrog Geo, Leapfrog Edge, and Central to connect geological modelling and resource estimation across its global operations—from Greece to Turkey to Canada. Teams can now log in from anywhere to access the latest models, identify changes, and collaborate seamlessly.

This shift delivered key benefits, including:

Global collaboration, real-time access:
Stakeholders can view, compare, and comment on the latest models from anywhere, supporting better decisions across sites and time zones.

Faster estimation cycles:
With Leapfrog Edge, model updates trigger rapid regeneration of resource estimates, enabling iteration in minutes, not hours.

Simplified data management:
Central is the engine behind this, providing controlled versioning and secure web access to every model.

Read the full story →

> With the Geo and Edge integration, if we make changes to a 3D shape, it is regenerated within the application. In 15-20 minutes of processing time, we can have an updated resource estimation."
>
> **Sean McKinley**
> Senior Geologist, Eldorado Gold

CHAPTER 3

Connecting 3D geological modelling to mineral resource estimation workflows for better outcomes

Seequent eliminates the barriers created by siloed workflows by providing an intuitive, visual, and seamlessly connected workflow that integrates geological modelling and resource estimation in a single environment.

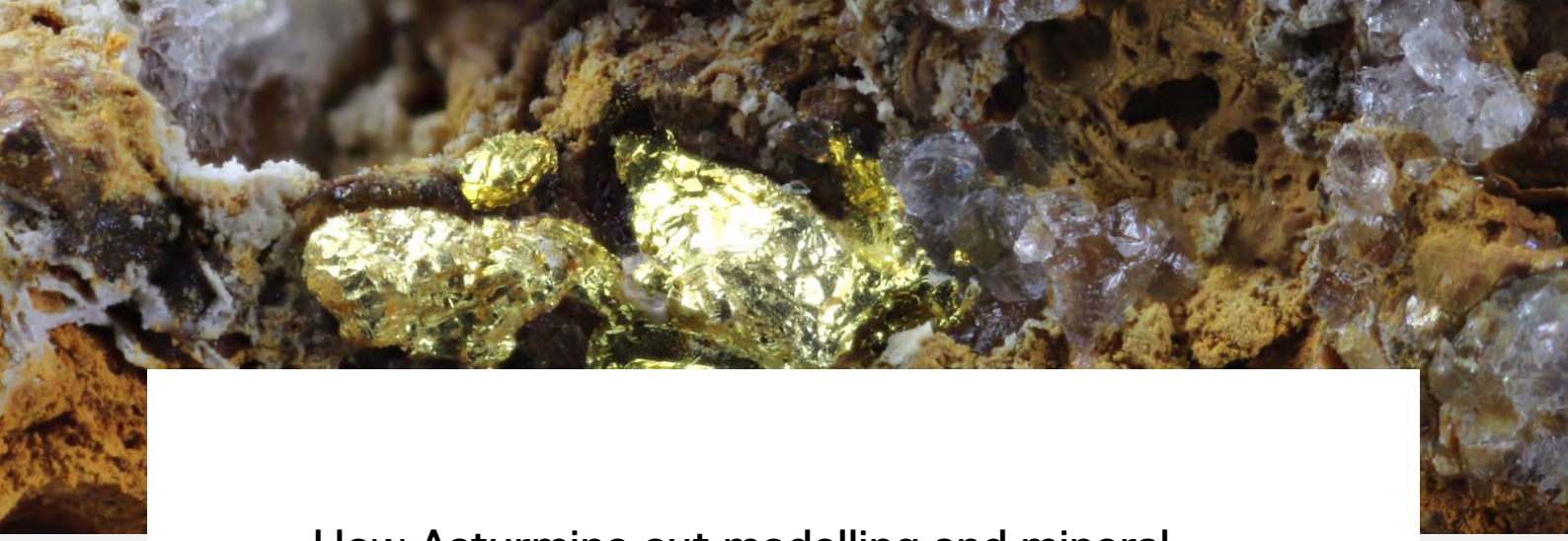
With Leapfrog Geo and Leapfrog Edge working together on one platform, users can build geological models and move directly into estimation without switching systems, reprocessing data, or losing context.

Geological interpretations flow naturally into the estimation process through dynamic model updates, helping teams iterate with confidence and consistency.

Leapfrog Edge puts the power of geostatistical modelling directly in users' hands. Built on the same intuitive interface as Leapfrog Geo, it enables faster upskilling and broader participation across teams. Compelling 2D and 3D visualisation—along with tools like 3D variogram modelling and graph highlighting—helps users analyse structural trends, grade patterns, and search neighbourhoods with greater clarity.

To support defensibility, every estimation parameter change is tracked automatically. Users can export a detailed parameter report and audit log, making it easier to meet reporting standards such as NI 43-101 and JORC. Flexible estimation methods—including kriging, inverse distance, and radial basis function (RBF) allow users to tailor their approach to the complexity of their deposit.

With built-in tools for validation, transparent reporting, and seamless integration, Seequent's connected approach turns estimation into a collaborative, iterative, and risk-informed process—ready to scale from early-stage exploration to long-term mine planning and production.



How Asturmine cut modelling and mineral resource estimation time by 30%

Asturmine, a mining consultancy based in Spain, was tasked with developing a grade control model for a complex polymetallic vein system in Kazakhstan.

Initially reliant on explicit modelling and manual data transfer, their workflows were time-consuming and error-prone, taking up to eight months to build models across hundreds of domains.

By adopting Leapfrog Geo and Leapfrog Edge, Asturmine reduced modelling and MRE calculation time by 30% and automated updates across more than 700 veins. With dynamic, connected workflows and integrated 3D variogram modelling, the team could generate and revise estimates faster, with greater clarity and confidence. Key outcomes included:

- **30% reduction in modelling and MRE calculation time** by eliminating manual rework and import/export steps
- **40% reduction in mineral dilution,** improving design accuracy, and lowering waste
- **Improved ESG performance** through targeted extraction and lower environmental impact

Read the full story →

> Before, modelling a complex mineral deposit took eight months. Now, with Leapfrog Edge, we can model more than 700 veins in just two—and keep the estimates updated."
>
> **Juan Antonio Fernández García**
> Senior Mining and Geological Engineer, Asturmine

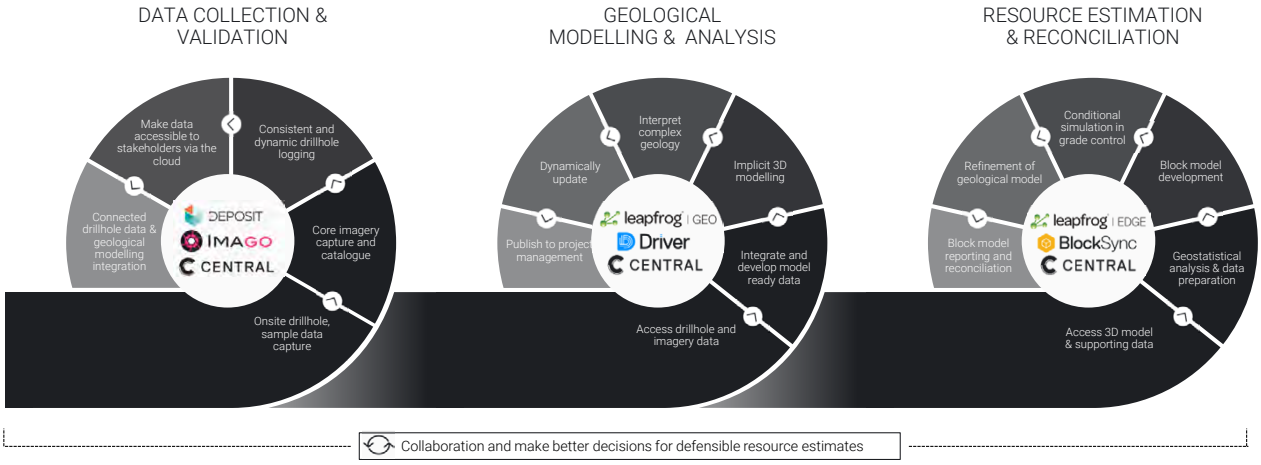
From data collection to mineral resource estimation through connected tools

Seequent's Leapfrog Geo and Leapfrog Edge are recognised as the leading 3D modelling and MRE solutions in the mining industry. Trusted by thousands of geoscientists worldwide, the software has become essential in both exploration and production geology due to its combination of speed, flexibility, and user-friendly interface.

Leapfrog Geo and Leapfrog Edge form part of a comprehensive suite of solutions designed to enhance subsurface understanding and streamline resource management and estimation workflows.

> I have used Edge from day one. It is impressive to see the connectivity between the geological models and the estimation."
>
> **Gabi Brandau**
> Director of Orebody Knowledge, Teck Resources

Mineral Resource Estimation connected workflow



Capture data with Imago

The quality and accuracy of geological models depend heavily on the data that feeds into them. With Imago, Leapfrog Geo users can capture, manage, and share high-resolution images of core samples, outcrops, and other geological features in real time. Imago's ability to work seamlessly with Leapfrog Geo means that these images can be directly linked to geological data, enhancing both the model's visual quality and the geologist's ability to make informed decisions. This real-time image capture, accelerated by machine learning, not only saves time but also ensures that geoscientists are working with the most up-to-date and detailed data available.

Manage data with MX Deposit

Managing drillhole and sample data is a crucial part of any exploration project. MX Deposit is a cloud-based solution that simplifies the collection, management, and sharing of this data, ensuring that all stakeholders have access to a single, reliable source of information. Used with Leapfrog Geo, MX Deposit allows users to bring vast amounts of drillhole data into their 3D models, streamlining the process of data management and interpretation. This ensures that geoscientists can quickly update their models with the latest drilling information, driving better decision-making and reducing project timelines.

Centralise block model data with BlockSync

BlockSync redefines how teams manage, analyse, and connect their block model data, offering an open, auditable system of record where teams can collaborate on block model data from any source. Rapid model updates and real-time resource insights enhance orebody knowledge and support strategic and operational decision-making. When used with Leapfrog Geo, users can collaborate on the same model data simultaneously and make updates to subsets of the model, whether volumetric or attribute-based subsets. Conflict management rules ensure that any changes are appropriately managed with new versions.

Accelerate drilling data analysis with Driver

Driver is a cloud-based rapid analysis tool that supports spatial exploratory data analysis of drilling datasets. Integrated machine learning automates analysis of numerical data (e.g. assays) and categorical data (e.g. lithology) so teams can quickly understand the structure of their deposit, understand domains, and make better downstream models, with less manual effort and no coding. Users can more efficiently discover complex 3D lithological or grade relationships, reveal mineralisation trends and structural deposit features, and intelligently classify and group data. Structural trend information can be easily incorporated into Leapfrog models without manual processes.

Connect and collaborate in the cloud with Seequent Central

Leapfrog Geo and Leapfrog Edge become even more powerful when they publish directly to Seequent Central, a secure, cloud-based hub for models, data, and discussion. Central streams objects from Leapfrog and other Seequent tools into the same project, allowing exploration, resource, and geotech teams to view the same data in the same space. For example, model updates from Leapfrog Geo instantly kick off re-estimation in Leapfrog Edge, then republish to Central, keeping all project stakeholders in sync.

Future-ready with Seequent Evo

While Central provides today's collaboration backbone for Leapfrog Geo and Leapfrog Edge, Seequent Evo is the next-generation platform that will unite data, compute, and AI across the mining lifecycle.

Integrated cloud compute: Run heavy geostatistical tasks such as conditional simulation without local hardware constraints.

Open, extensible ecosystem: APIs let teams link Evo to existing scripts or build custom apps; native Evo apps like BlockSync and Driver are available day one.

Same Leapfrog DNA: Leapfrog Geo and Edge connect directly to Evo workspaces, so models and estimates flow into advanced analytics—or back to the desktop—seamlessly.

Evo's scalable architecture positions resource teams to exploit machine-learning insights, automate repetitive QA/QC, and collaborate across disciplines—all while maintaining the auditability regulators demand.

How Seequent's integrated workflow enables better collaboration and more reliable estimates

A resource geologist's work involves a great deal of collaboration. They must analyse data from exploration geologists, mine geologists, and resource development geologists to generate estimations using a block model, which are then provided to a variety of stakeholders to support key business decisions. They collaborate with internal and external stakeholders, including technical services, mine engineering and operations, finance, and board-level decision-makers, to find opportunities for optimising resource extraction. For this reason, it's crucial to produce a secure, auditable, and versioned resource model that's accessible to all stakeholders for collaboration or review.

Evo provides a single, cloud-based source of truth that automatically versions every change made, who made it, and supplemental comments for context. Stakeholders can download, view, or update the centralised data from anywhere, subject to role-based permissions.

Blocksync extends this governance to the block model itself, so users always know which tonnage/grade table they are reporting. One-click reports retain a full audit trail, eliminating the error-prone Excel copies common in file-based workflows.

With BlockSync and Leapfrog, multiple users can update volumetric or attribute subsets concurrently—built-in conflict rules promote clean new versions. At the same time, Edge's swath plots make inter-version differences immediately visible.

Evo's open APIs mean the same block model can feed Jupyter notebooks, PowerBI dashboards, or third-party mine-planning suites, without breaking the chain of custody.

The result is a simplified, secure workflow between teams for better collaboration, transparency, and decision-making.

CHAPTER 5

Leading the future of geoscience: Innovation, education, and collaboration

At Seequent, our commitment to geology runs deep. As a company built by geoscientists for geoscientists, we are constantly pushing the boundaries of what's possible with innovative tools and technologies. By combining technical expertise with user-centered design, we have created a portfolio of solutions, like Leapfrog Geo and Leapfrog Edge, that not only enhance the way we understand the subsurface but also make complex geological processes more accessible and intuitive.

Inspiring the next generation of geoscientists

We recognise the need to inspire and equip the next generation of geoscientists. This is why we developed Visible Geology, a free, web-based application designed to bring geological concepts to life for students and educators alike. Visible Geology moves beyond traditional 2D teaching methods and empowers students with an immersive 3D learning experience.

With its intuitive 3D modelling capabilities, collaborative classroom features, and digitised stereonets, Visible Geology helps students grasp fundamental geological concepts in a captivating way. Educators can seamlessly integrate this tool into their curriculum, modernising the learning experience and engaging students with interactive topographies, cross-sections, core samples, and more.

By encouraging students to explore the subsurface world in an innovative digital environment, Seequent is playing a key role in shaping the future of the geoscience field.

See Visible Geology for more →

Understand the underground to build a better world.

Seequent is evolving the way organisations work through better subsurface understanding.

As the world leader in subsurface earth-modelling, analysis and data management, and collaboration software, Seequent is at the forefront of building a collective understanding of the Earth.

We hire amazing people who collaborate with our customers to find technology solutions to their challenges that deliver more positive outcomes for a better world.

As The Bentley Subsurface Company, Seequent connects our natural environment with the built world so organisations can manage the impact of their projects at every stage.

Seequent: Understand the underground.

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