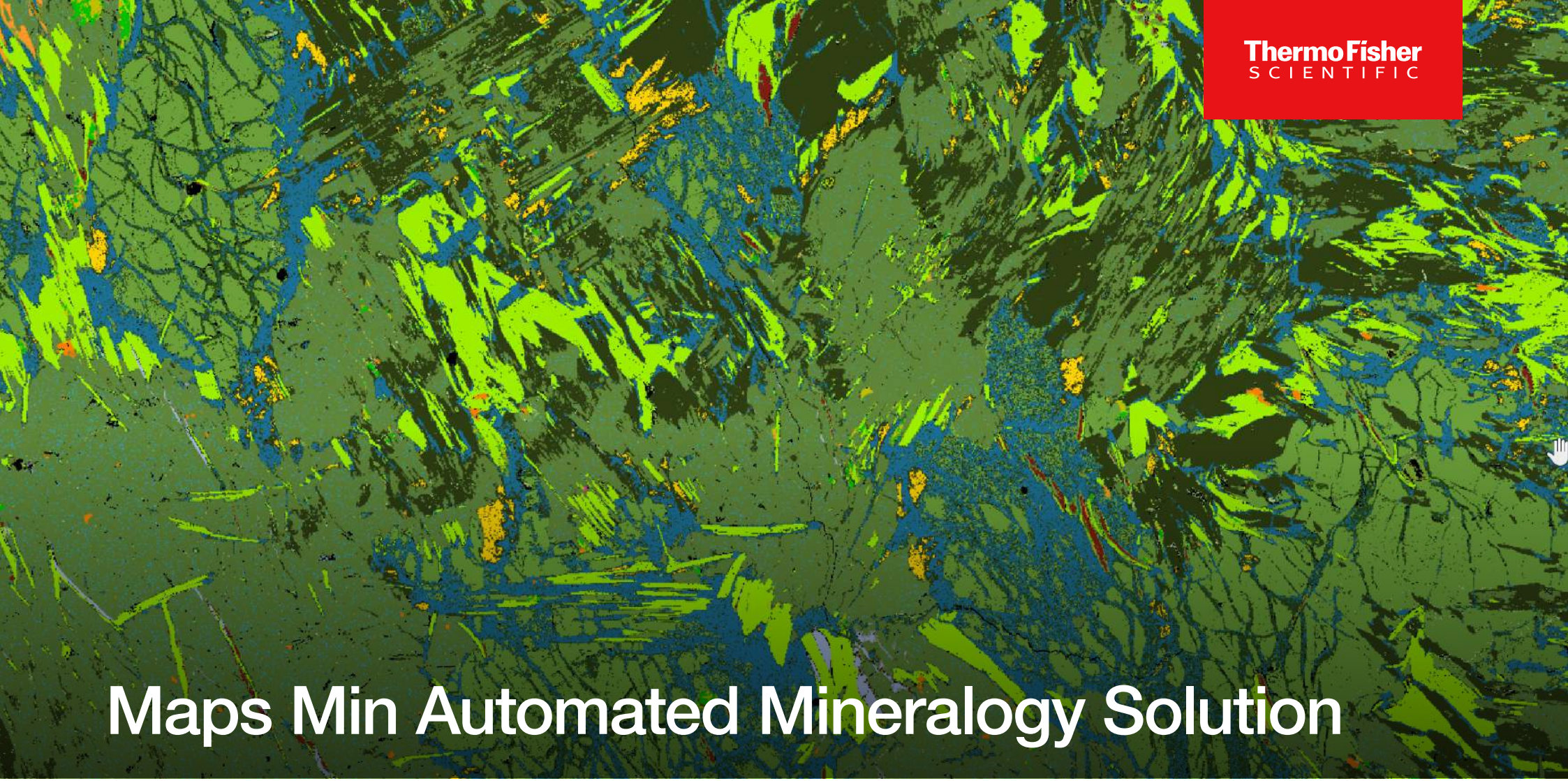


ThermoFisher SCIENTIFIC

Maps Min Automated Mineralogy Solution

Next-generation characterization for mineral processing

thermo scientific

Understanding the properties of natural materials starts with accurate mineralogical characterization. By combining mineralogy with the mineral texture, or microstructure, you can determine the physical and chemical properties of earth materials ranging from bulk samples to ground particulate materials processed at a mine site.

Automated mineralogy has been a mainstay in minerals processing for decades. The unique ability to derive compositional and mineralogical insights is a key component in evaluating and optimizing mineral separation techniques. Recently, academic researchers have frequently linked rapid mineral identification with spatial data to interpret mineralogical textures more objectively.

However, changing problems and needs in the industry require a new approach. Based on our experience building QEMSCAN and MLA, Thermo Scientific™ Maps Min Software brings automated mineralogy into the present with modern computational approaches that aim to make the technique more objective, provide more repeatable results, and help you address even the most complicated textures and mineral systems.

Maps Min Software is comprised of a suite of applications that gather, analyze, visualize, and report mineralogical data. With a user-friendly interface that makes it easy to objectively analyze accurate data, Maps Min Software can help you push the boundaries of mineralogical characterization.

Acquisition

Simplicity is the main driver of any automated technique. How can we take the multiple functions necessary to operate and run a microscope and make the experience as straightforward as possible?

Maps Min Software's acquisition system is built around Maps Software, our well-established EM automation platform. After sitting down at the microscope, you can start collecting data with a few clicks.

Autofunctions, templates, and modern user interfaces

Modern SEM systems have evolved a lot in the past decade. Autofunctions that actually work and superior beam stability have changed the reliability and consistency of data. When using the Thermo Scientific™ Apreo 2 SEM with Maps Software, for example, you can quickly set up automated acquisition even while working remotely.

The template approach within Maps Software allows you to pre-define a list of go-to acquisition approaches tied to sample or ore type, particle or grain size, or throughput goals. You can easily apply any template to a polished section without having to manually set parameters. Templates also add a safety net, ensuring that all users follow standard protocols and limiting time wasted collecting data using an incorrect approach.

Modern user interface design makes navigation simple and requires fewer clicks to get where you need to go. This operational efficiency makes the system easy to use and, most importantly, makes it easy to train new users on the technique.

Building the right approach with acquisition modes

Balancing resolution and throughput is key for optimizing automated mineralogy data collection. Regardless of approach, Maps Min Software decouples the resolution of electron imagery and EDS, so you don't have to sacrifice textural details for speed. You can independently set EDS and electron resolutions, which becomes important when reviewing results and linking mineral texture to the mineral ID.

Two base acquisition modes—grid and centroid—come standard, with highly customizable options to optimize data collection.

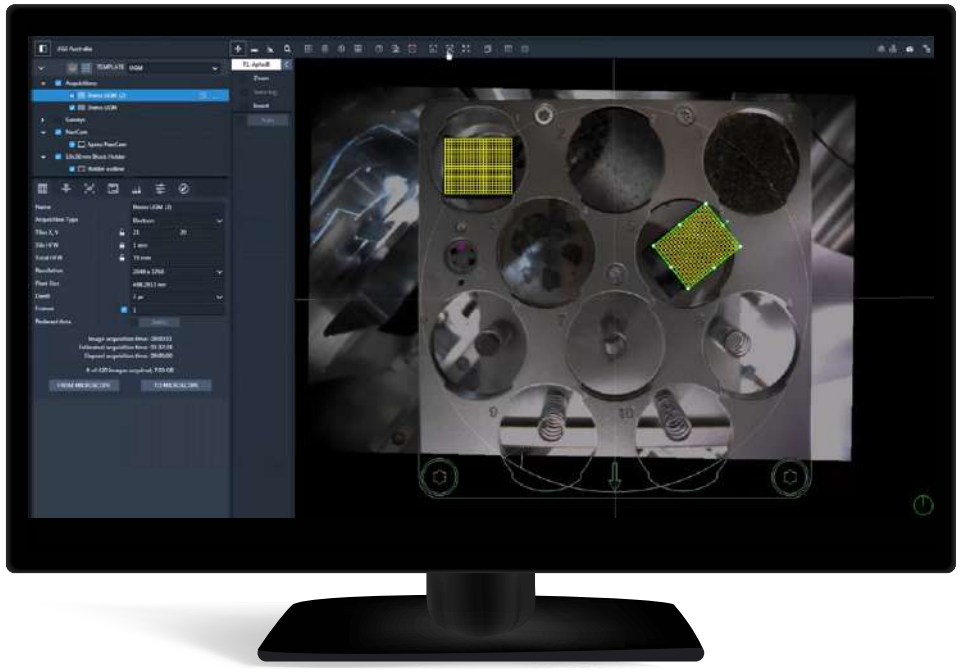


Figure 1. Maps User Interface illustrating acquisition set up, highlighting the flexibility when setting tile set locations and alignment.

Maps Min Software acquisition provides

- A user-friendly environment that is easy to learn and train
- Access to microscope autofunctions that ensure consistency in data collection
- Operational efficiency by deploying SOPs via templates for acquisition set up

Analysis

At the heart of Maps Min Software is its approach to mineral phase identification.

Nearly a decade of development and over 13 granted patents have translated to a robust, more automated approach. The Mixel algorithm provides accurate mineralogy and limits the need for QC and post processing. It also has built-in intelligence that goes beyond simple spectral matching and solutions, ultimately taking advantage of some of the limitations inherent in the physics of X-ray generation within the SEM.

Save time with improved objectivity and accuracy of data output

The Mixel algorithm works by not being limited to a single phase definition required for a single spectrum collected from a sample.

For example, the X-rays generated as the beam approaches a boundary between two or more grains of different minerals are fundamentally mixed, which would cause other automated techniques to fail. When using other approaches in automated mineralogy, including QEMSCAN and MLA, you would have to manually create a special entry to fill in these unclassified locations. You would also need to build a cumbersome mineral library for data processing that incorporates a huge combination of potential mixtures.

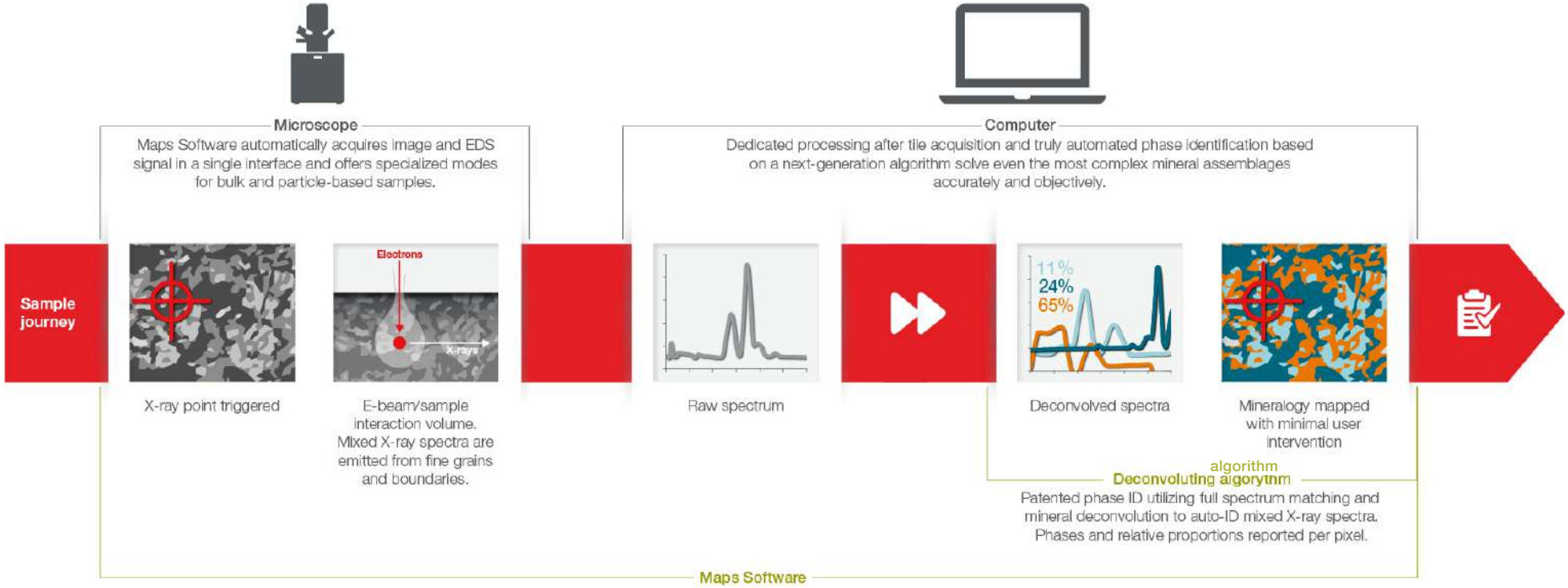


Figure 2. Schematic overview of the Mixel algorithm approach.

The Mixel algorithm in Maps Min Software can process these mixed spectra automatically. The spectra can be matched with the identity of the minerals present as well as the relative proportions of those identified phases.

Mixel technology is especially powerful and valuable for samples that contain fine-grained mineral and boundary textures, microcrystalline groundmasses in volcanic rocks, cryptocrystalline rocks, and small inclusions. The deconvolution also allows for accurate identification and quantification of sub-species in solid-solution series, including compositional zonation (e.g. plagioclase, chromite-spinel) and trace or minor element substitutions (such as As in pyrite or Fe in sphalerite).

Maps Min Software automatically detects which sub-species of a solid-solution is present in your sample—all you have to do is add the solid-solution end members to the mineral library and link them as a solid-solution series. There is no need to add intermediate compositions as separate mineral definitions because the software will automatically determine the composition present in the sample using its Mixel spectrum deconvolution.

Taken together, these approaches save time after acquisition and lessen the impact of user bias on the results. With the Mixel algorithm, you can spend less time validating data, take on more projects, and gather accurate, high-quality mineralogical data.

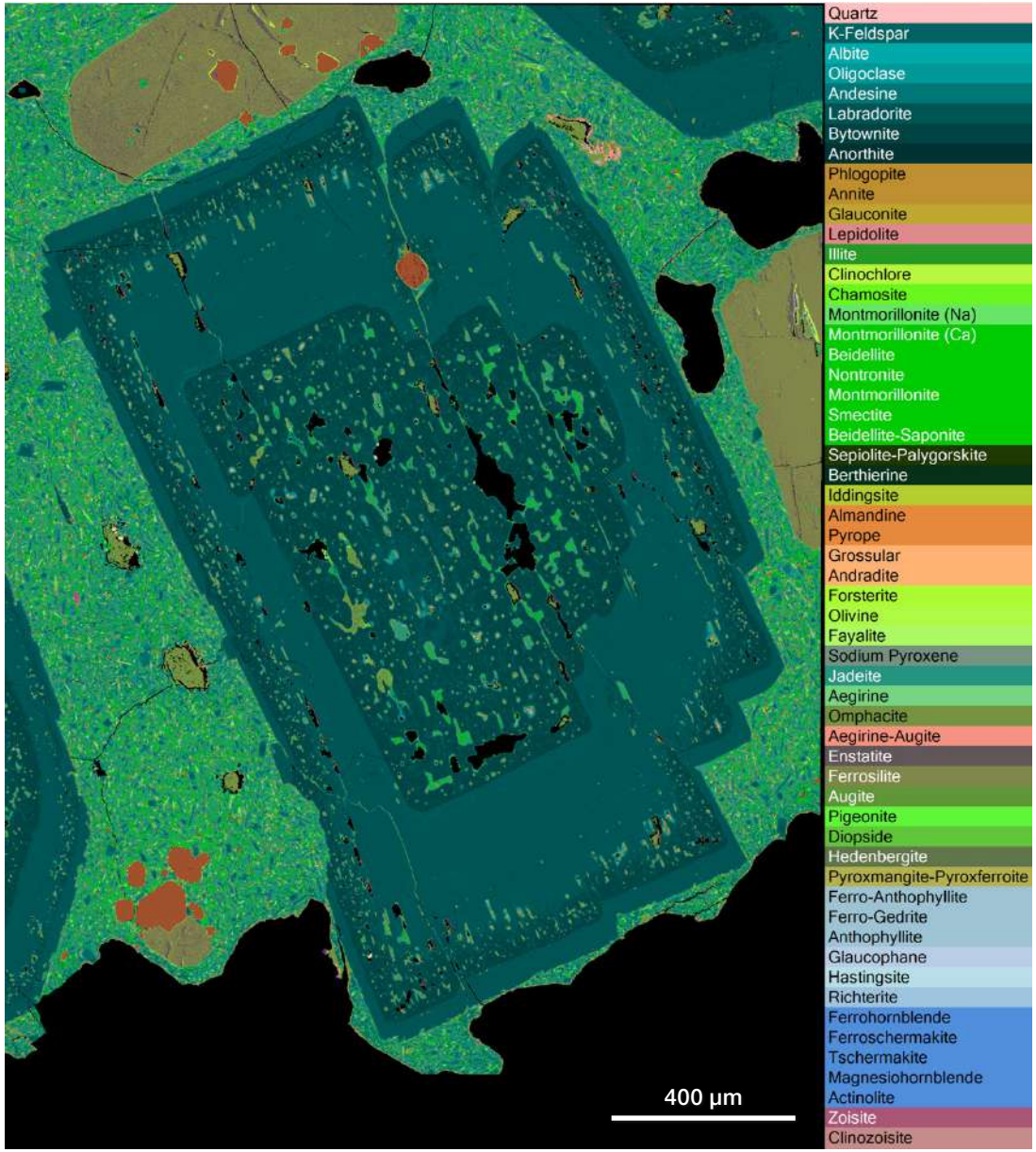


Figure 3. Maps Min Software map of a large plagioclase phenocryst surrounded by an ultrafine-grained volcanic matrix. The Mixel algorithm approach along with Maps Min Software's unique support for solid-solution phases enable the characterization of Plagioclase compositional variation as well as accurate mineral identification of the fine-grained matrix phases.

Simplified mineral list management and improved accuracy for chemical quantification

Along with a more modern approach to mineral phase identification, we've also greatly improved mineral list management. A single mineral list can be applied to any acquisition approach or microscope parameter, even if you have more than one SEM system. Once built, the list can be fully customized based on common sense variables related to the realities of how mineral chemistry is taught.

Maps Min Software comes with a default list of well over 4,000 mineral species. A subset of these entries was built using high-count, high-resolution EDS spectra that also inform our standards-based elemental quantification built into the classification routine.

You can easily customize, remove, or add new species using three different methodologies:

1. Generate a new entry from EDS spectra
2. Add a new species from our library using a lookup search
3. Create a new entry based on chemical data from a microprobe or other source

In addition, phase entries do not have to be minerals. They can be any material that has a known chemical composition that is diagnostic of that phase.

Once in the environment, you can easily customize a phase based on known potential trace elements or elemental exchange vectors. All of this is designed to be easy to understand for anyone familiar with basic mineral chemistry.

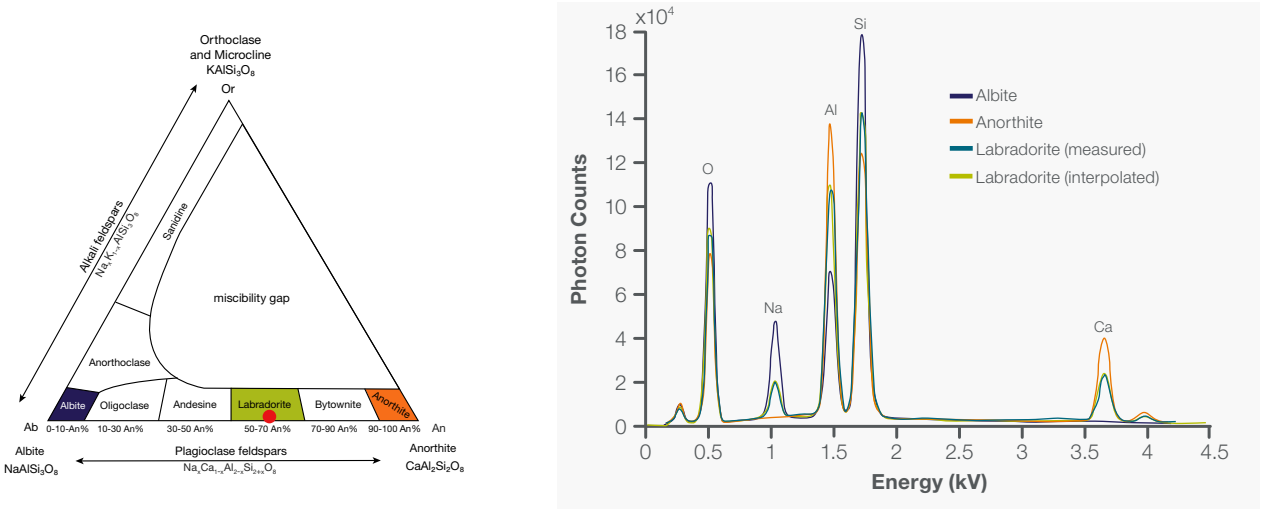


Figure 4. (Left) Standard ternary feldspar phase diagram. The red dot illustrates the location in feldspar composition space mapped by the Mixel algorithm for an individual pixel. (Right) Example spectral solution showing the albite-anorthite endmembers of plagioclase as well as the resolved intermediate plagioclase composition, labradorite, identified for the measured spectrum.

Figure 5. Illustration of the Mineral Reference Editor user interface. This UI is where users can edit, customize and control the phase identification algorithms within Maps Min Software.

Once acquired, every mineral entry—and by extension the modal mineralogy—is quantified based on the EDS spectra collected. This is counter to other approaches in which chemical data are back calculated based on mineral formulae input into the mineral list. Each identified mineral species is associated with a sum spectrum of every pixel containing that phase. The result is a high-count spectrum that is more accurately quantified than the individual spectra collected at the pixel level (generally <4,000 X-ray counts).

This helps you perform better quantification and look for the presence of trace elements. Bulk composition of the material is also based on this technique.

This mineral quantification approach leads to:

- More accurate elemental deportment
- Bulk compositions and assays that are more representative of the sample material
- Tracking of key trace elements
- Quantification of potential penalty elements as well as accurate diagnosis of what mineral phases they are associated with.

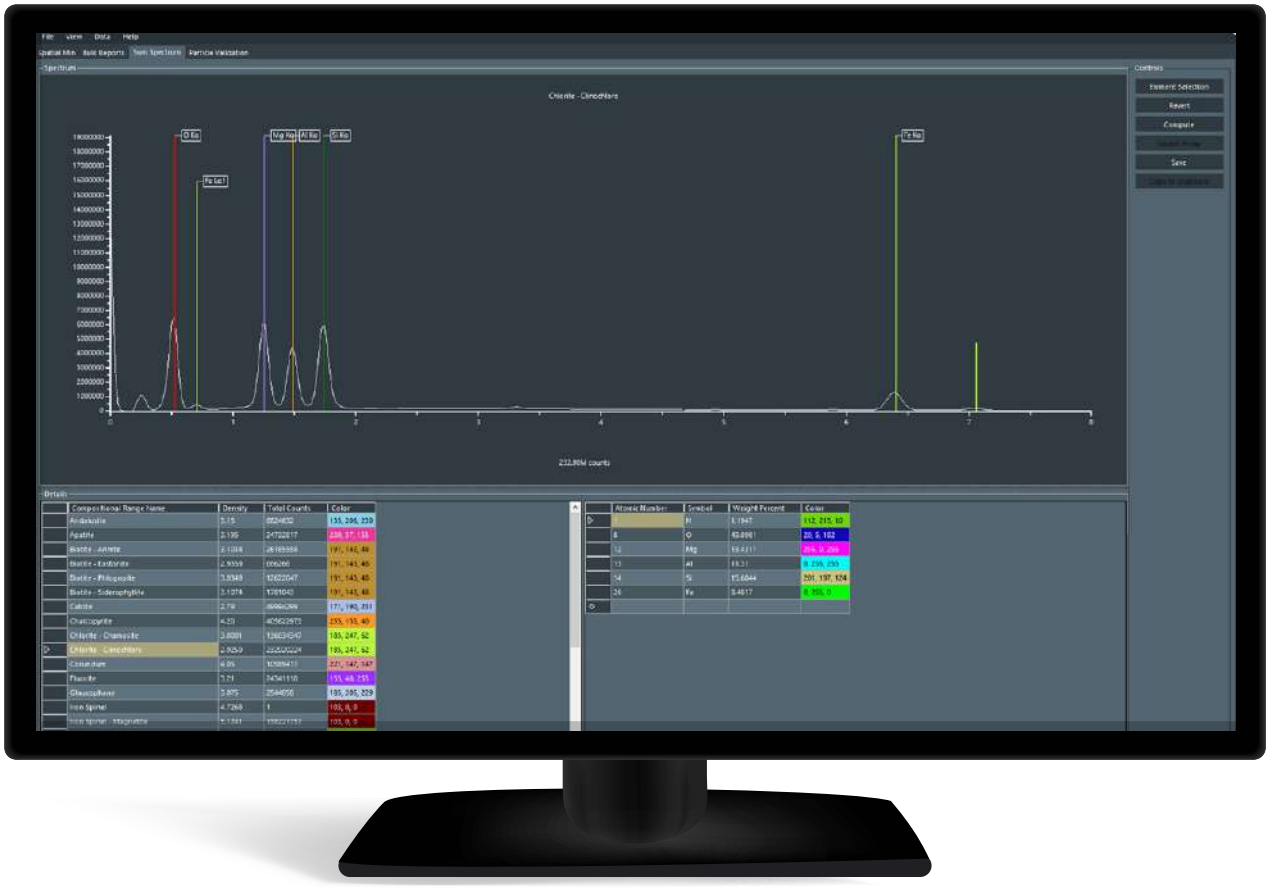


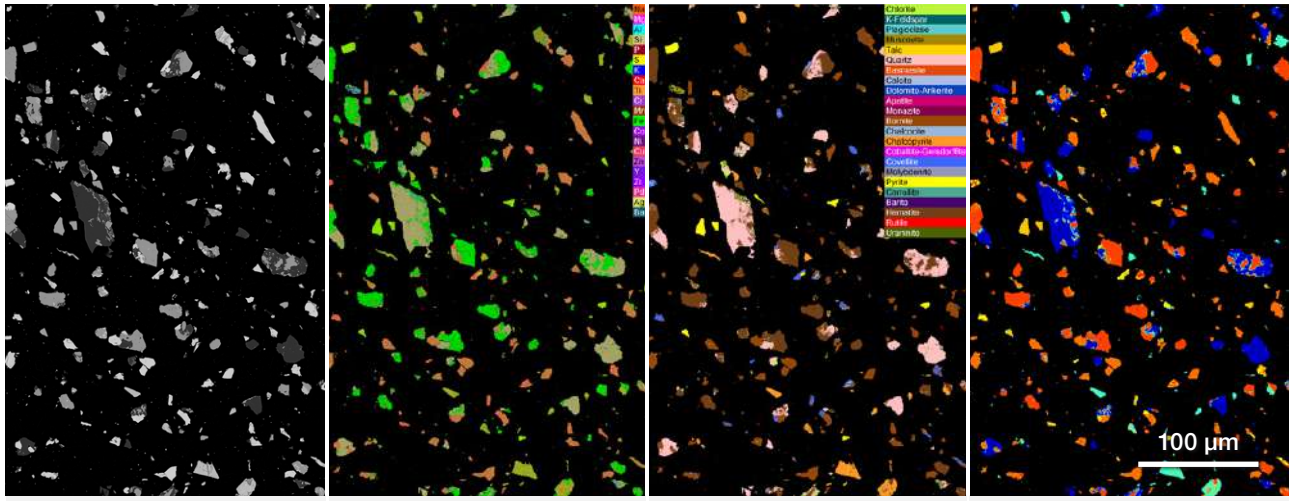
Figure 6. Example of the spectral quantification approach for Maps Min Software. Each mineral identified during the analysis results in a summed spectrum of every identified pixel of that mineral. The result is a high-count composite "super spectrum" that permits accurate standards based quantification of the elemental content of each phase identified. The approach also enables spotting trace element content not possible from individual pixel analysis.

Visualization and reporting

Maps Min Software aims to provide the most accurate mineralogy possible out of the box.

The dedicated data inspection UI enables mineralogical data QC, reprocessing, and particle validation to ensure high data quality. With a single click, you can change views between mineralogy maps, BSE imagery, EDS-elemental maps, and special QC modes to visualize X-ray counts, spectral match statistics, and other properties that help validate the mineralogical result.

Once data validation is complete, Maps Min Software offers single-click export of multiple projects and samples for report building and visualization. The data structure is based on an open architecture environment—you can access the central database to connect third-party software or perform custom scripting access for advanced data analysis.



Decoupled BSE-EDS resolution automated field stitching	Elemental overlays single-click selection	Mineral overlays single-click selection	Multiple QC overlay options: spectral match, physical properties, X-ray count rate

Figure 7. Schematic representation of the data types that are collected/calculated by default in Maps Mineralogy. Every spatial map is accessible via a single click to make data interpretation as focused or broad as necessary when reviewing results or preparing for publication.

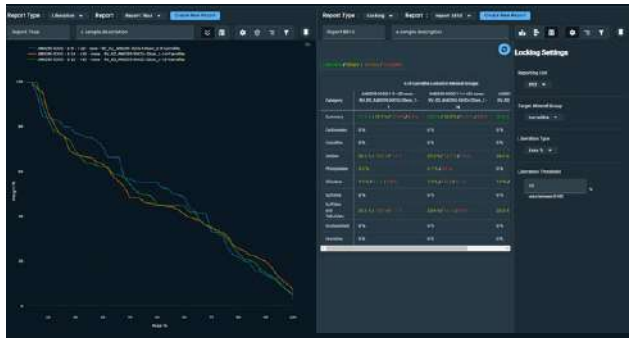


Figure 8. Liberation and locking characteristics of carrollite are displayed side by side in the Report Browser UI.

A modern UI and centralized data management streamline operation

Maps Min Software's reporting structure is built around a centralized data management package. Once data are validated, they are pushed to the reporting server location. You can then access the data over the internet to visualize and manipulate data right in your web browser. Multiple users can access the same location, simplifying data management and access. There is no need to copy data, move it to different locations, or copy it to hard drives for further processing.

The contextual UI was built with users in mind. All reports have their own set of options and settings fully visible with no hidden menus or right clicking needed to access data.

You can access a set of the following auto-calculated reports for visualization:

- Modal mineralogy
- Elemental deportment
- Grain and particle size charts
- Liberation
- Locking and associations
- Particle visualization

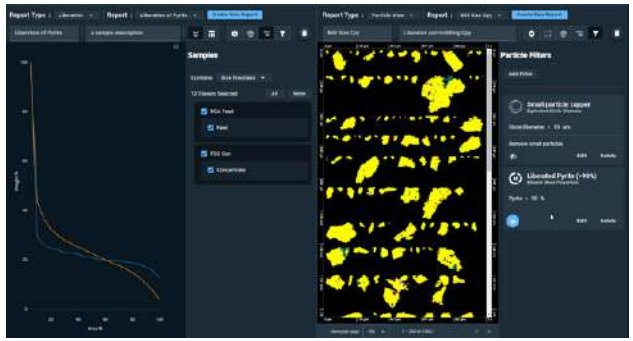


Figure 9. Example of Report Browser UI showing liberation analysis of pyrite alongside a visualization of the particles to review impact of user-defined particle filters on the liberation data.

Figure 10. Report view showing modal mineralogy data for multiple samples in tabular and graphical representations of the data.

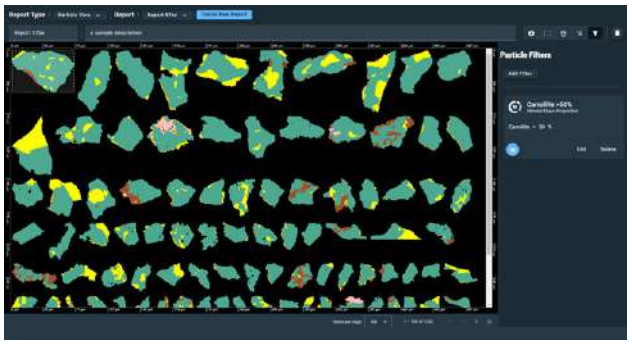


Figure 11. Particle View mode for the Report Browser. Users can review the mineralogy or BSE-based imagery while utilizing filters to prepare data for report finalization and data export.

The reporting server handles multiple sample reporting. If desired, you can, with one click, combine size fraction data output or replicate data to visualize the rolled-up results of these measurements.

In addition, you can easily manage the reporting mineral list by grouping or ungrouping minerals and by customizing names and colors for clear presentation.

Finally, you can also easily filter data using a single filter or a string of filters to locate the data necessary for reporting. The same filters can be applied across all the reports in the project. Once reports are finalized, a single click exports charts and images into a set of files for easy incorporation into workflows outside of the software.

Maps Min Software reporting enables:

- Extreme ease of use for both data access and data sharing
- A single, non-proprietary reporting database
- A modern, contextual UI that streamlines access to data visualization tools
- Filtering, live particle sorting, and visualization of reports

Maps Min Software is the next generation of automated mineralogy techniques, built on the tradition of over 30 years of knowledge in leading the approach.

About Thermo Fisher Scientific

We are the world leader in serving science. Our Mission is to enable our customers to make the world healthier, cleaner and safer.

Step ahead. Step beyond. Duration 1.33

Our innovative solutions for electron microscopy, surface analysis, and microanalysis help materials science researchers advance their sample characterization to gain deeper insight into the physical and chemical properties of materials from the macroscale to the nanoscale. Our multiscale, multimodal solutions cover a broad range of applications across dozens of industries and research fields, serving customers in academia, government, and industry. Our TEMs, DualBeam™ FIB-SEMs, comprehensive portfolio of SEMs, XPS, and microanalysis solutions, combined with software suites, take customers from questions to usable data by combining high-resolution imaging with physical, chemical, elemental, mechanical, and electrical analysis across scales and modes.

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At Thermo Fisher Scientific, we will not let budgetary constraints stand between you and your next great discovery.

We are your one-stop partner for the best laboratory products and analytical technologies available, plus the unique financing options you need to accelerate success in science or industry.

Cost-effective financing designed for each individual customer is key to any successful capital equipment solution.

We understand not just your advanced technology and application requirements, but the business challenges you face when financing your critical equipment assets. For decades, we have worked closely with businesses, hospitals, universities, and municipalities to provide flexible financing terms to support their successful operations.

If you are looking for off–balance sheet financing, accelerated ROI, technology protection, or cash flow management, our innovative financing options can help meet your company's budgetary needs and bottom-line goals.

We also offer instrument maintenance and training services.

Explore equipment leasing and financing options

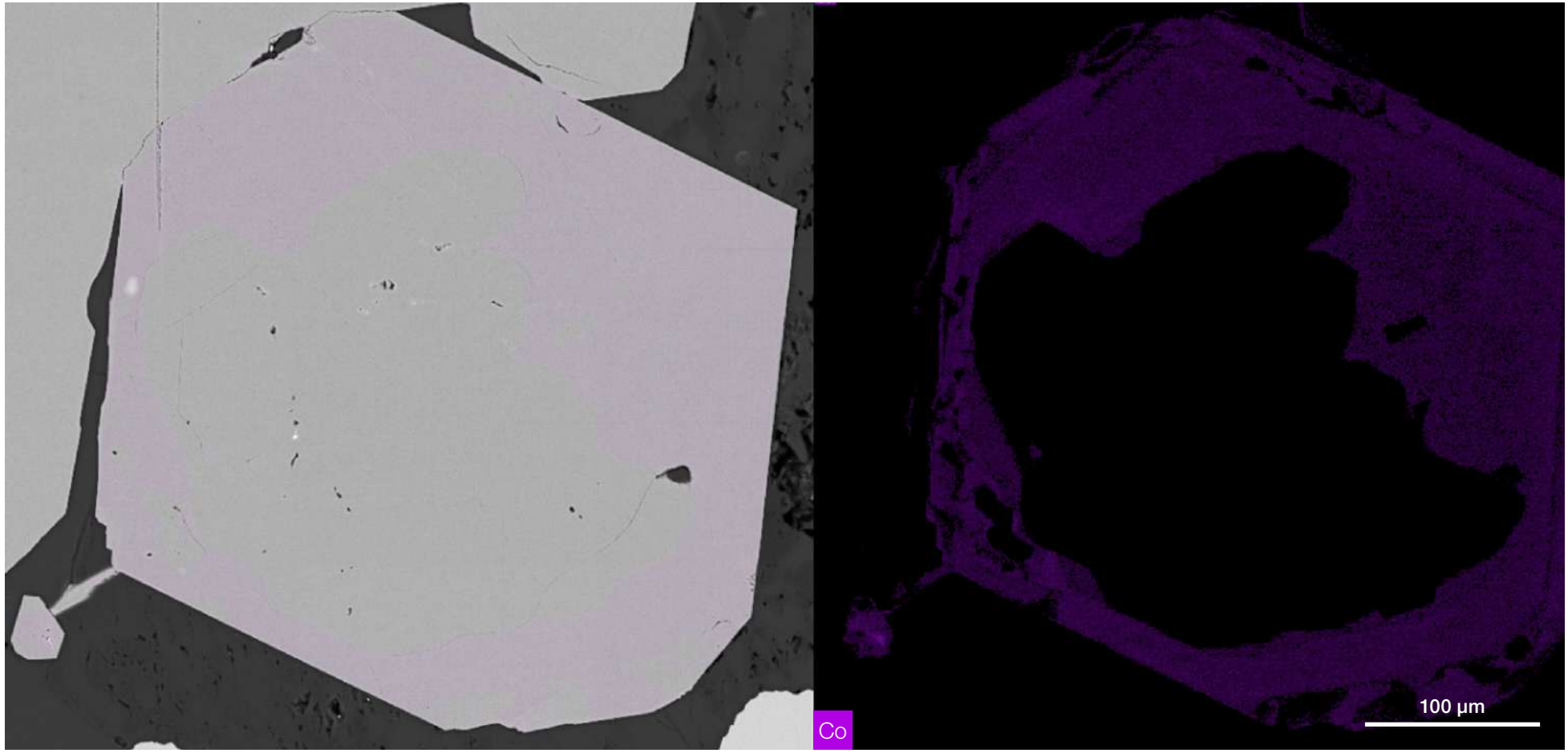

Figure 12. Cobalt content in pyrite. (Left) Co elemental map overlay on BSE image. (Right) Co elemental map.

Learn more at **thermofisher.com/maps-min**