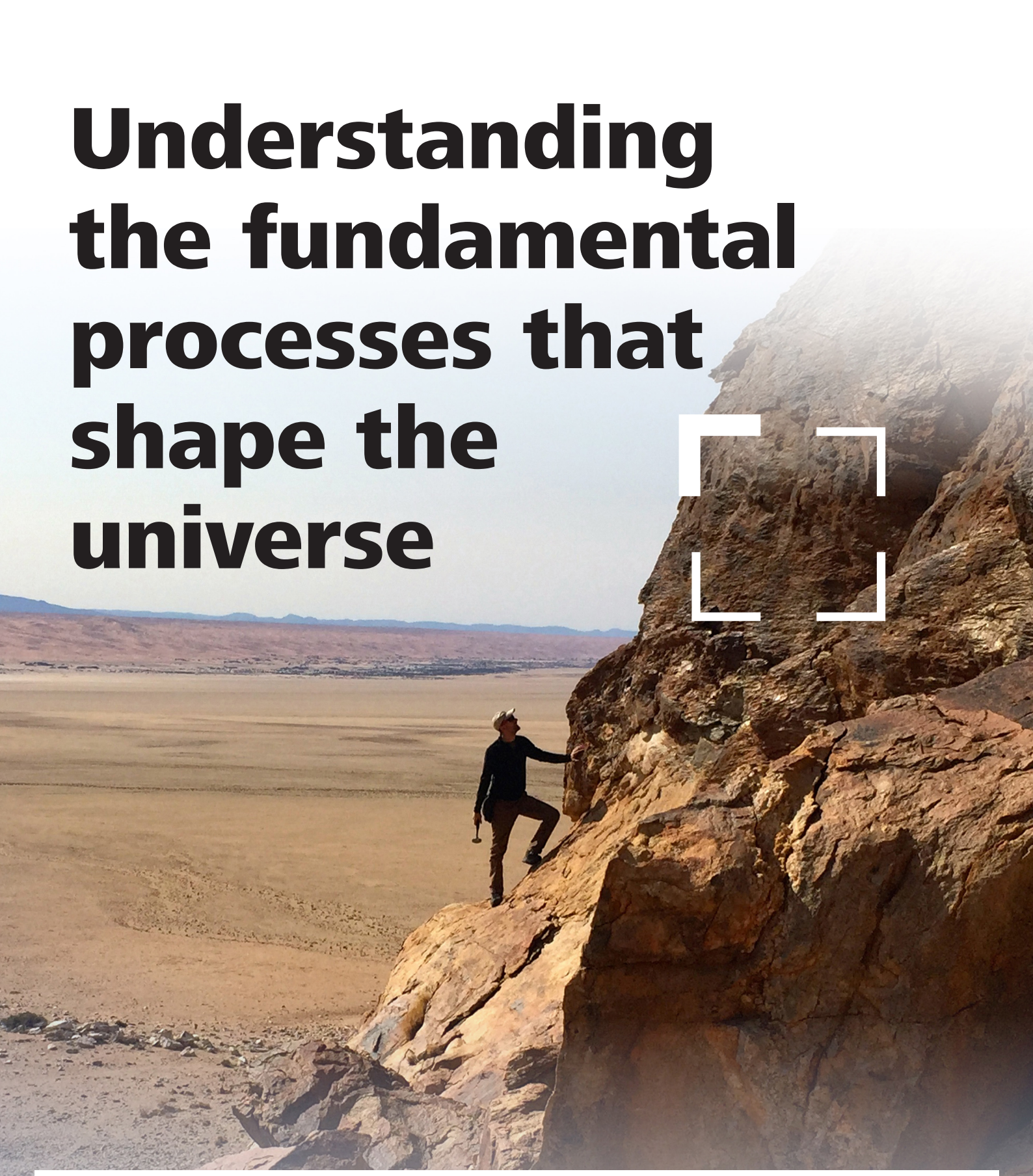
Understanding the fundamental processes that shape the universe



ZEISS Microscopy Solutions for Geoscience

ZEISS

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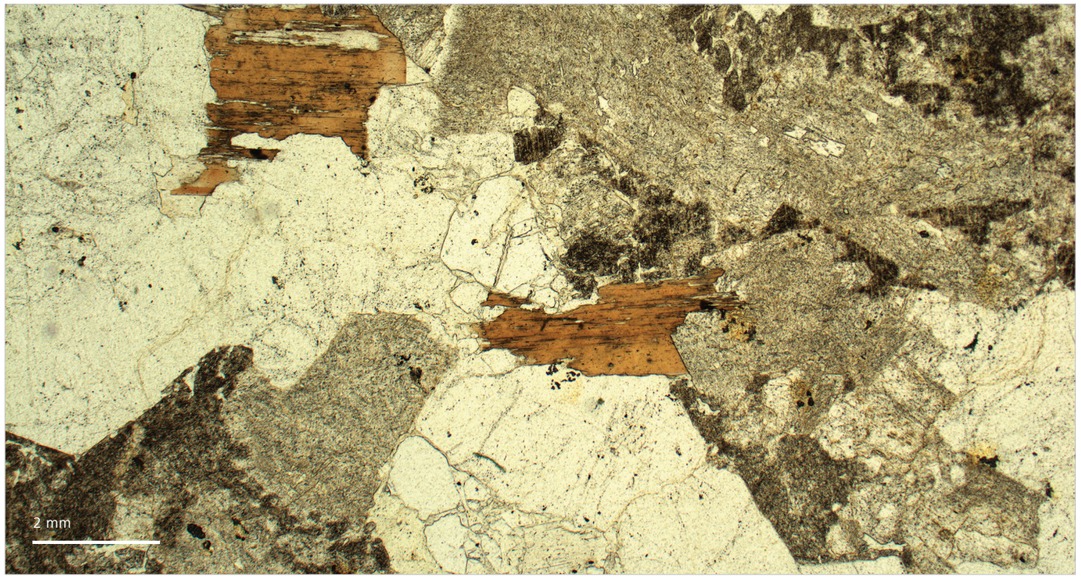
Seeing beyond

Geoscience

Geoscience is a critical fundamental research topic focused on the examination of processes that govern the formation and evolution of the world around us. It also underpins the processes that control its economic development and utilization. From micropaleontology to mineralogical studies to the modeling of three-dimensional fluid flow, ZEISS Microscopy has provided geoscientific imaging and analysis solutions for over one hundred years. From educating the next generation of geoscientists to the latest advances in technologies such as non-destructive 3D X-ray microscopy and quantitative mineral mapping, ZEISS enables you to gain unparalleled knowledge from your geoscientific specimens from the macro- to the nanoscale.



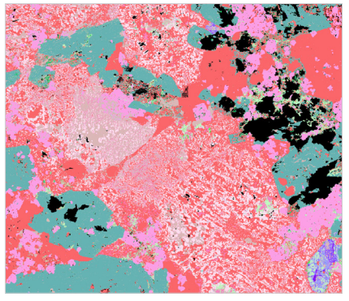
Green - brown biotite books with pleochroic haloes.

Geoscience Research

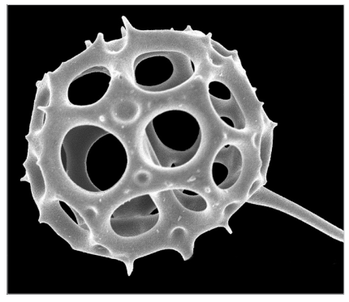
Understanding the fundamental processes that have shaped the Universe

Fundamental investigations require the highest data integrity, image quality and collaboration across scientific disciplines. Gaining a greater understanding of the Universe on a fundamental level is possible by performing more detailed analyses across a wide spectrum of technologies and length scales.

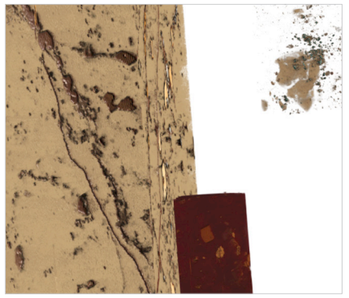
ZEISS offers the widest and most advanced portfolio of microscopy techniques. Correlative solutions enable you to seamlessly incorporate data from a variety of analytical techniques, providing you with an easy-to-use environment that correlates images and data, and also enables global collaboration. Incorporating data from optical, electron and X-ray microscopy enables you to understand samples from a multidimensional perspective. These integrated multi-modal data can then be passed through powerful new machine- learning algorithms, enabling transformative new techniques for geological microanalysis.



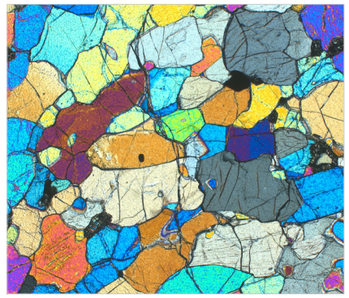
Peralkaline granite: showing rare earth elements.
ZEISS Mineralogic



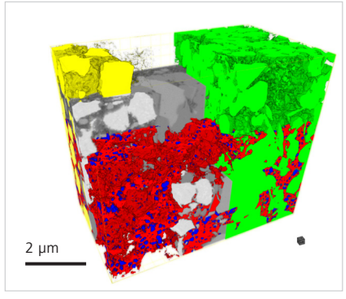
Biostratification of foraminifera: protists with shells made of silica.
ZEISS Sigma scanning electronic microscope with backscattered imaging

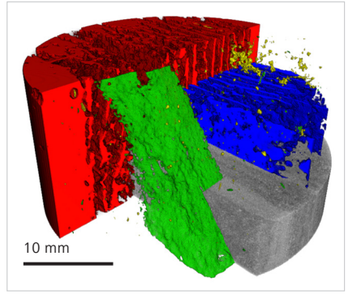


Volume segmentation showing interior location of gold in core sample.
ZEISS Xradia Versa X-ray microscope

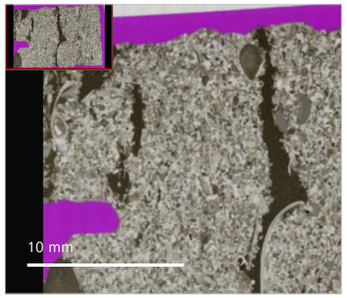


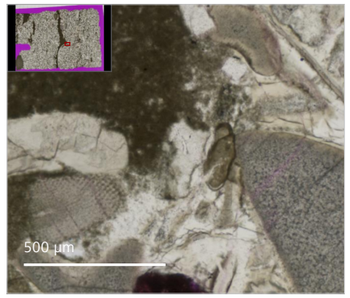
Dunite: circular polarization.
ZEISS Axio Imager





Fracture in a sandstone created using integrated in situ *uniaxial load cell.*
Imaged with ZEISS Xradia Versa 3D X-ray microscope.





Multiscale big data visualization with a Google Earth-like view of carbonate sample using web-based interfaces.
Data captured by ZEISS Axioscan 7 Geo automated petrographic thin-section scanner.

Sedimentology

Perform detailed investigations of clastic, carbonate and evaporitic rocks and understand weathering and erosion processes that both shaped the geological features of the Earth and defined the conditions necessary to generate crude oil in conventional reservoirs.

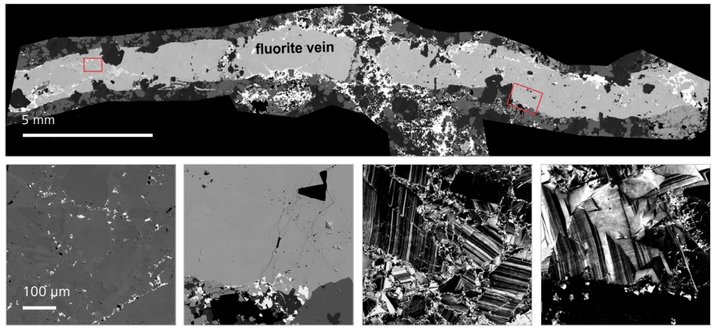
Use automated grain size and shape measurements to understand environmental conditions of formation and use correlative microscopy to blend mineralogy data from polarized light microscopes and automated mineralogy to provide textural knowledge.

Determine stratigraphic sequences from micro-fossils through both SEM imaging and X-ray microscopy. Use detailed data on the organism's structure to identify species and development level to provide geological timescales of formation.

Geoscience Research

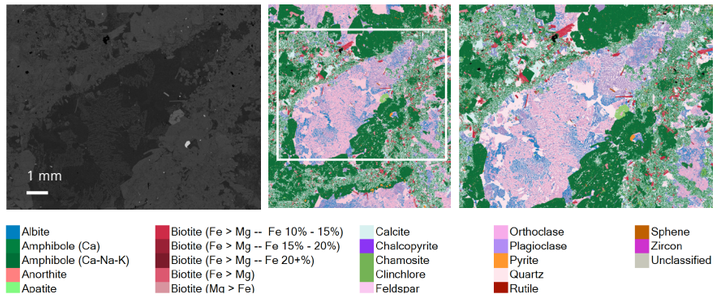
Small carbonaceous fossils (shrimp-like crustaceans) in mudrock samples from the Cambrian age imaged with ZEISS Axio Imager.
Image courtesy Dr. Tom H.P. Harvey, University of Leicester, UK

Igneous & Metamorphic Petrology
ZEISS microscopes have been used to analyze and describe magmatic, volcanic and metamorphic processes for over 100 years. Advances in technology allow researchers to now quantify mineral distributions, automate large-scale analyses, and describe structures in 3D, and integrate all of this data together to facilitates a better understanding of the dynamic forces that shape the world around us.



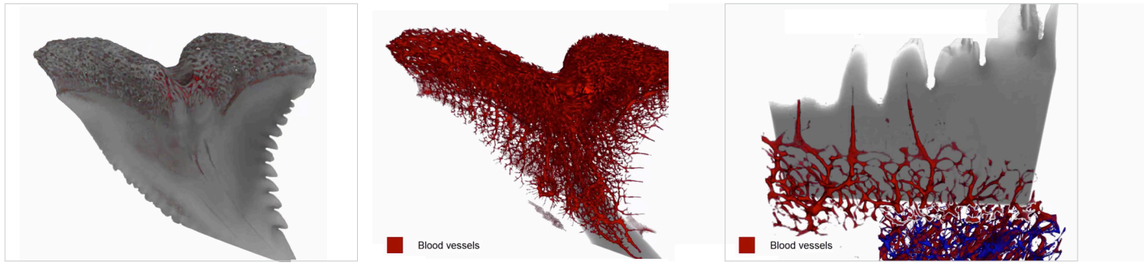
Zircon samples with fluorite vein imaged with cathodoluminescence.

The high throughput digitization of optical thin sections provides a map for high resolution analyses. These analyses can range from automated quantitative mineralogy using EDS to more complex microanalysis techniques. These could include the coupled imaging of zircon zoning using cathodo-luminescence detection and correlative workflows to LA-ICP-MS (laser ablation inductively coupled plasma mass spectrometry).

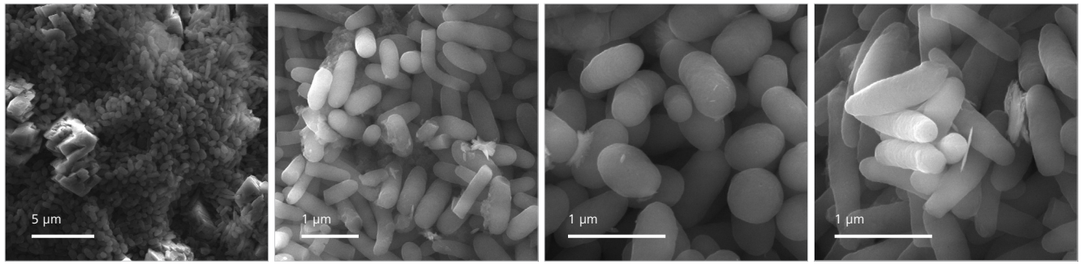


Mineralogic scan of Scottish Lamprophyres showing feldspathic inclusions with myrmekite exsolution of quartz in a mixed feldspathic (plagioclase, albite and orthoclase) matrix.

You can even integrate multiple microscopy techniques with machine learning analysis to automate rapid, large-area mineral classification over a wide range of length scales.



Interior tomography of shark's tooth fossil. Image entire tooth at low resolution to find macroscopic blood vessel distribution. Conduct high resolution interior scan to identify dentin, enamel, recrystallized nerve bundle and sheath, blood vessels. Locate individual blood vessels serving each tooth.



Photomicrograph from ZEISS Sigma 300 using the SE detector and Atlas 5 showing the oblate and cylindrical melanosomes from the fossilized eye of T. gregarium.
Image courtesy of Prof Sarah Gabbott, University of Leicester, UK

Paleontology
Paleontology allows researchers to unlock the secrets of the billion-year history of a living Earth. Traditional paleontological research has required samples to be removed from storage media or cut out from their host rock.

Non-destructive imaging of irreplaceable samples can be accomplished using multiscale 3D X-ray microscopy. This allows you to make 3D morphological measurements on internal structures without interfering with the sample in any way.

Additionally, high resolution micropalentology using scanning electron microscopy allows you to examine structure down to the nanometer scale. Large area automated and high resolution imaging allows for large samples to be scanned to provide high resolution yet contextual understandings of your samples.

Geoscience Research

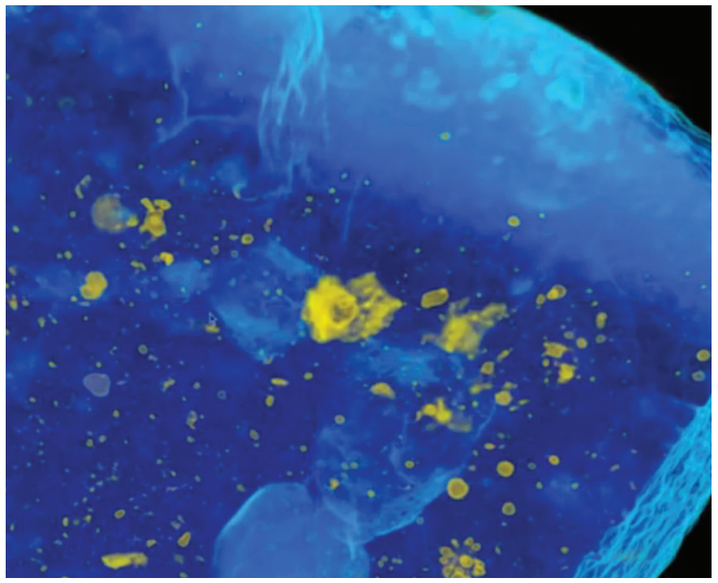


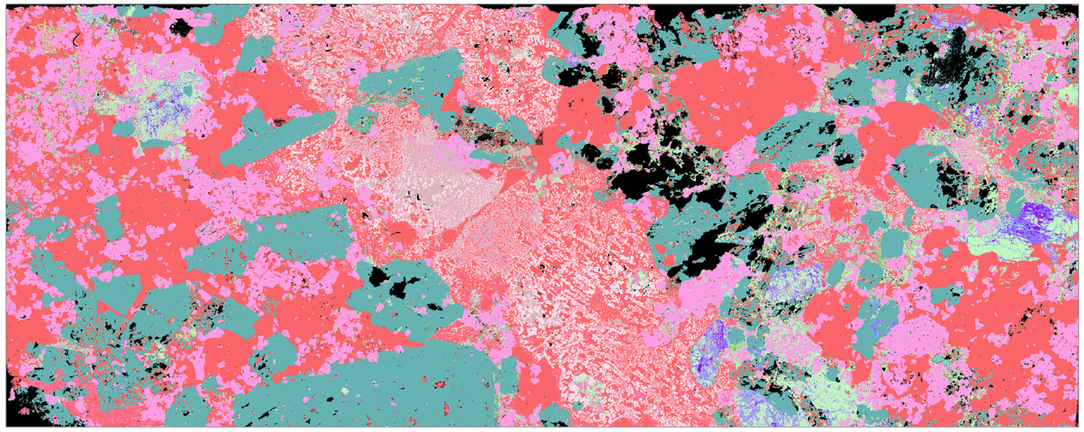
Image precious samples non-destructively. Rare 4.5 billion year old Sutter's Mill carbonaceous chondrite meteorite. CT imaging with ZEISS Xradia Versa X-ray microscope. Iron or iron sulfide (yellow) in a matrix (blue) containing Mg, Si, Al, Ca, C, and O. Image width = 9 mm. Courtesy of Prof. Qing-Zhu Yin, University of California at Davis, USA.

Planetary Geology
The processes that govern the formation and evolution of the universe are imprinted at the smallest of scales. Astro-geoscience requires a detailed understanding of the mineralogy and structure of samples from extra-terrestrial sources.

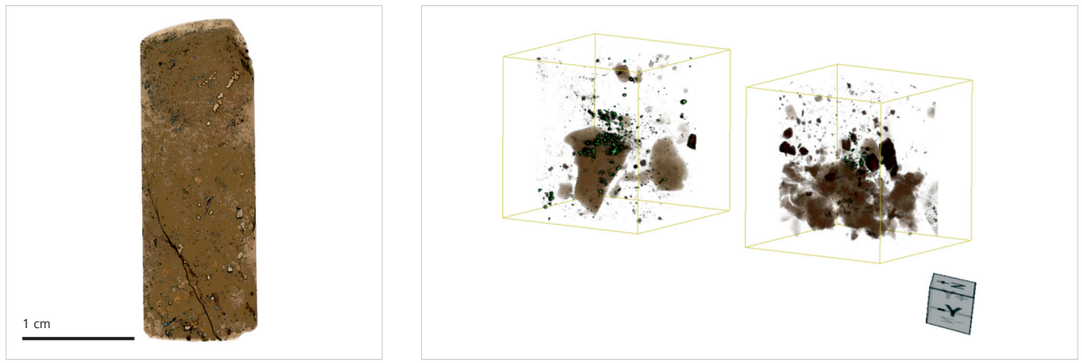
The most treasured and chemically sensitive samples can be examined using non-destructive, large-sample imaging using three-dimensional X-ray microscopy. This allows for structures to be imaged without cutting or even removing them from specialized protective environment.

Microanalysis of precious samples can be challenging due to the requirement of coating for traditional electron microscopy techniques. ZEISS Nano-Variable Pressure (Nano-VP) removes this requirement, allowing for the examination of uncoated, unaltered samples.

By integrating microstructural analyses from a range of sources – including optical, X-ray, electron and ion – and operating at a range of scales researchers can gain deep insight into the physical and chemical processes governing the formation of our planet, solar system and universe.



Peralkaline Granite, Northern Quebec, Canada, containing rare earth elements, including a fluorite vein that crosscuts the sample and zoned zircons.



"Scout" the entire drill core (segmented to show the different mineral groups of silicates and sulphides) and then "Zoom" to show the gold mineralization particles using non-destructive 3D X-ray microscopy.

Ore Body Research
Improving ore deposit knowledge, refining our understanding of ore-genesis and understanding more effective ways of extracting valuable ore is critical in ensuring we have resources available for future generations.

For these studies we can combine optical, electron and X-ray microscopy to help characterize and understand these ore deposits. 3D analysis using X-ray Microscopy enables large area, high resolution and non-destructive characterization of samples. These volumetric analyses require little sample preparation and are perfect for identifying precious metals in low concentrations eliminating issues associated with 2D sampling and preparation.

SEM-based automated quantitative mineral analysis is available to provide a quantitative mineralogy characterization of these samples. Data outputs such as elemental deportment can help locate and understand the distribution of target, by-product and deleterious elements. Liberation outputs provide valuable data for improving our understanding of how best to recover these minerals.

Reflected light analysis using optical microscopes can also be used to provide a final data layer to a comprehensive analysis capability for ore deposit research.

Geoscience Research

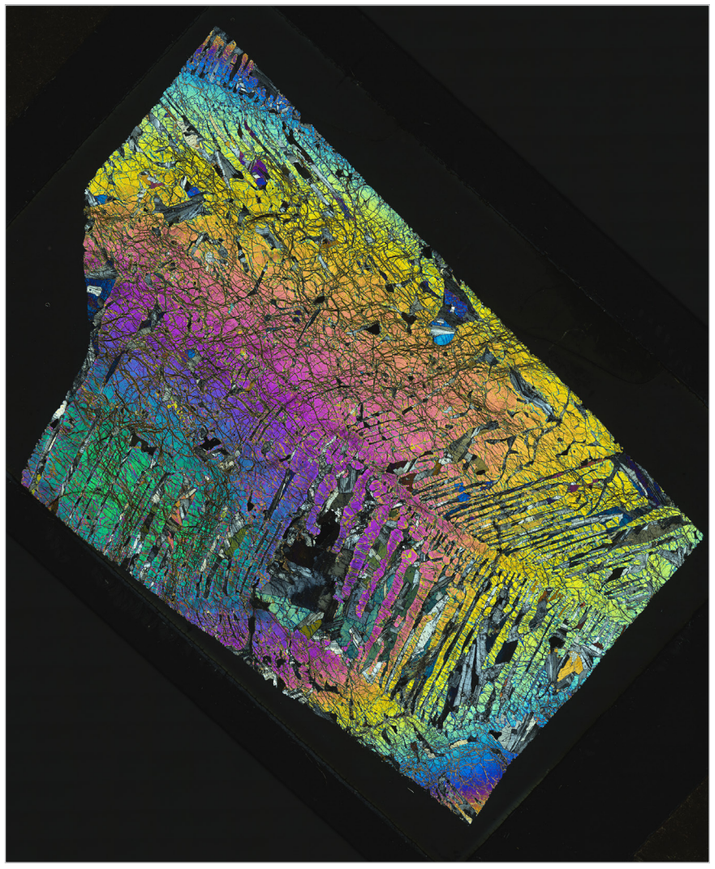
Contextual Mineralogy and Digitization of Collections
Often in mineralogical studies, we focus exclusively on small areas or mineral grains of interests. In doing this, we lose sight of the contextual setting of that region or grain in our sample. The digitization technology available from ZEISS provides a range of light, electron and X-ray solutions purpose-built for large area, high resolution data capture. These solutions are able to provide a correlated and contextual overview of your samples across different scales and modalities.

The digital age provides a wealth of opportunity for accessing, analyzing and sharing historic and archived collections. It is now possible to share an everlasting digital record of these valuable assets with other researchers, students and society at large. High-throughput automated optical petrography allows for thin sections to be fully-digitized in batches of up to 100 at a time. These data can then be uploaded to the cloud and visualized anywhere in the world through a web interface.

Access to rare and precious samples is limited to a few privileged researchers as their preservation is paramount. Use non-invasive X-ray tomography to create a digital, shareable archive of these materials.

These scanned fossils can then be 3D printed, allowing students, researchers and museum visitors to physically interact with curated collections without risk of damaging rare samples.

Combine these digitization techniques with sub-nanometer-resolution large-area imaging using scanning electron microscopy to gain insight into historical samples as never before.



Well-developed skeletal-textured olivine within an intrusive peridotite plug, Rum Layered Suite, Barkeval, Isle of Rum, Inner Hebrides, Scotland. A spectacular example of rapid crystal growth, resulting in single, optically continuous crystals. Sample courtesy of Prof. Alan R Butcher, Geological Survey of Finland.

Geoscience Education

Training the geoscientists of tomorrow

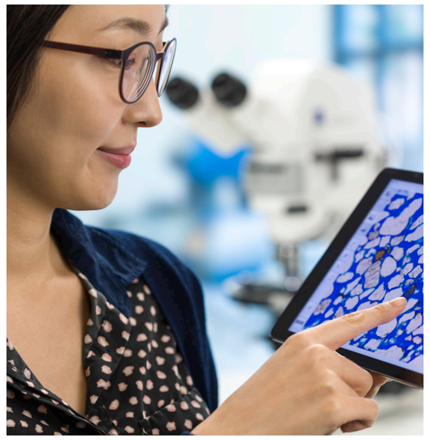
Training the geoscientists of the future is essential for the health of geoscience as a whole. The ZEISS teaching microscope portfolio offers a software platform enabling efficient and shared learning.

Geoscience education is focused primarily on data interpretation rather than the process of data acquisition. This has led to the demand for a greater focus on data sharing and interaction and a simplification of the hardware used to produce the data itself.

The rise of distance learning also drives a need for remote control and use of image and analytical data. In the university environment, blended learning is a growing application that incorporates both optical and electron microscope data to complement the subject you are teaching.

ZEISS Digital Geo Classroom provides a suite of interconnected WIFI enabled petrographic light microscopes that allow students to acquire, annotate and share their images. These are streamed directly to tablets, projectors or computer screens, driving engagement through the use of familiar digital technologies. It also allows the instructor to have a complete overview of the classroom, freeing the teacher to teach more efficiently.

Digital Classroom – WiFi-connected Primotech



Use a tablet to display images from any WiFi-enabled microscope in a hive. Annotate, share, and save images in collections using a tablet as the control device.

Available on the App Store

Matscope

Correlative & Analytical Core Facility

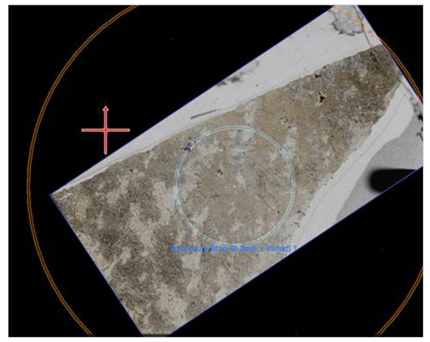
Many of the challenges faced by modern geoscientists require multiple analysis scales, modalities and technologies to solve. ZEISS' portfolio of light, electron, charged ion and X-ray microscopes are uniquely able to address these challenges due to their ability to integrate data, multiple modes and scales, allowing you to move from any system to any system.

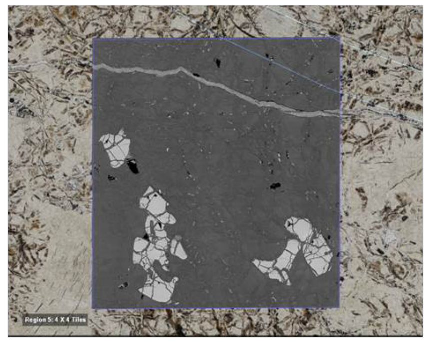
ZEISS electron microscopes provide a stable and expandable platform for a range of microanalytical techniques, allowing for energy dispersive and wavelength dispersive X-ray spectroscopy(EDS/WDS), micro X-ray fluorescence (uXRF) mapping, RAMAN microspectroscopy, electron backscattered diffraction (EBSD), and cathodoluminescence (CL) to be performed on the same sample in the same instrument concurrently.

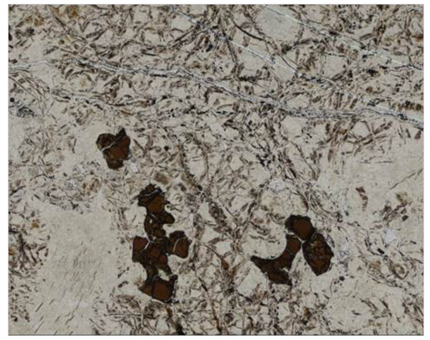
High throughput automated optical petrography allows for whole thin sections to be digitized. This data can then be taken into powerful correlative software on an electron microscope.

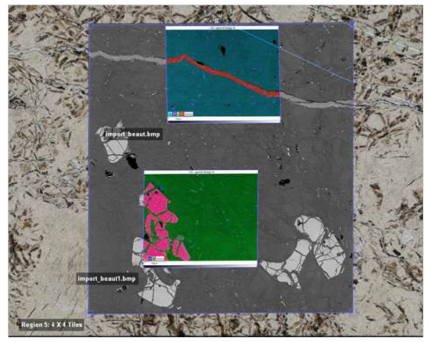
This allows for nanoscale analytical data to be contextualized within a true understanding of macroscopic sample heterogeneity. This software provides a "Google Earth," or micro-GIS type capability, for your sample, allowing you to navigate and zoom in on features of interest.

These workflows can be directly extended to any other microscope in the ZEISS portfolio, including multiscale non-destructive X-ray microscopy and nanoscale 3D analysis using FIB-SEM.









Multiscale, multimodal imaging of an ophiolite, showing both a calcite-rich vein and a chromium-rich spinel. High resolution backscattered imaging and energy dispersive spectroscopy (EDS) maps spatially registered with large area overview of a thin section, digitized under plane polarized light.

ZEISS Products for Geosciences

ZEISS Xradia Versa 3D X-ray microscope with FPX
High resolution, non-destructive imaging of geological samples, including very large and precious samples.

ZEISS Xradia Context CT Imaging
3D non-destrucative large sample imaging at full field of view.

ZEISS Sigma 300 with RISE
Integrated electron and RAMAN imaging in a single correlative microscopy system.

ZEISS Sigma 300 field emission scanning electron microscope
Greater analysis flexibility and simpler workflows in the characterization of ores and sediments.

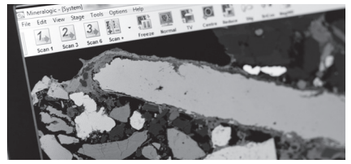
ZEISS GeminiSEM 450
High stability analytical design, three chamber sizes, flexible port configuration options and compatible mineral analysis software make EVO your scanning electron microscope for analyzing morphology, mineralogy and composition of geological samples such as zircons.

ZEISS Crossbeam FIB-SEM
High throughput 3D analysis and sample prep. Integrated imaging and analytical solution for understanding the challenges of flow and transport in unconventional resources.

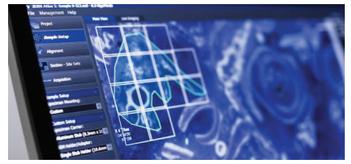
ZEISS Axioscan 7 Geo slide scanner for brightfield, fluorescence, and polarization
Digitize your specimens and create high-quality virtual thin sections automatically.

ZEISS Primotech wireless hive optical microscope
Wi-Fi enabled teaching microscope with tablet support and app control. Enables social viewing of images under the scope and has the ability to act as a node in a hive of teaching microscopes or as the teacher's microscope in the digital classroom.

ZEISS Axio Imager 2 for polarization with multi-phase software
Tailored to demanding analysis tasks. Benefit from crisp images, high optical performance and an automated workflow.

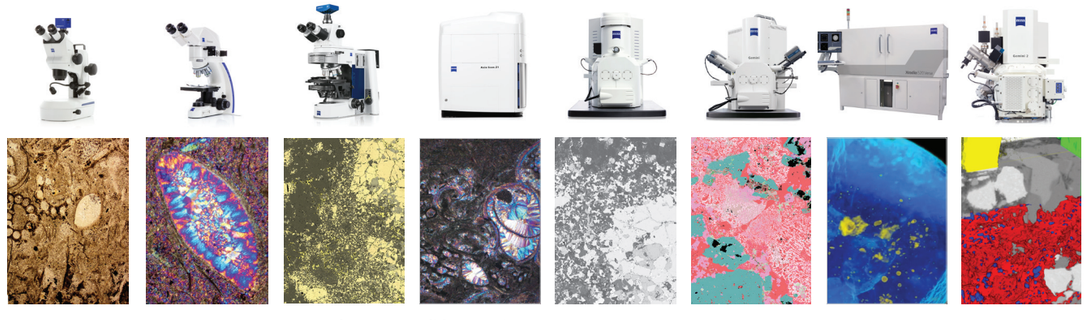


ZEISS Mineralogic
Automated mineralogy software for digital petrophysical analysis. Characterize rock texture with submicron precision using the industry standard in oil and gas automated mineralogy. Compatible with SEM and FIB-SEM microscopes.



ZEISS Atlas 5 Correlative microscopy workspace
Correlative microscopy for multi-scale, multi-modal, multi-dimensional imaging and analysis. Blended learning workspace enables remote control of instruments and collaboration across geographies and imaging modalities.

ZEISS ZEN Intellesis machine learning
Integrated, easy to use, powerful segmentation for 2D and 3D datasets available to the routine microscopy user.



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07745 Jena, Germany
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