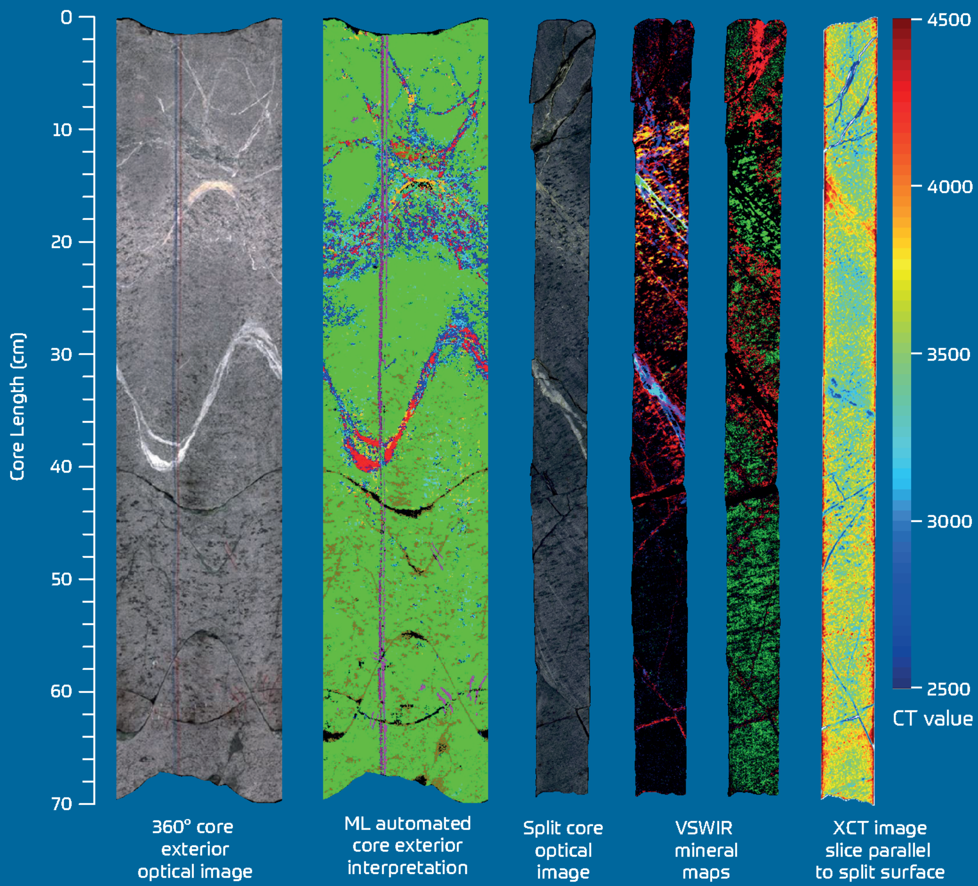
Data Innovation for Future Drilling

For many of the science goals laid out in the *2050 Science Framework*, the objective quantification of the subsurface is mandatory to reach useful conclusions and avoid misleading results. This applies to all rock types recovered by scientific ocean drilling but is especially true of hard rock coring, where recovery is usually incomplete and biased to more robust rocks. The rocks that record the greatest hydrothermal exchanges and biological activity are the most fragile, fractured, and/or altered. Core-log integration to characterize the missing materials remains challenging and human intensive and requires improved high-resolution imaging tools to more precisely locate these intervals.

New approaches already used by industry and some terrestrial scientific drilling experiments, such as the Oman Drilling Project in collaboration with the International Continental Scientific Drilling Program, allow cores to be more thoroughly recorded before splitting and further processing. Optical imaging of the external surface of cores freshly released from the core barrels provides high-resolution digital records of the cores when they are most intact, preserving context and enabling feature recognition and objective quantification by artificial intelligence/machine learning (AI/ML) approaches. Digital observations need not be restricted to the visual spectrum, and current photographic imaging of exterior and split surfaces can be supplemented by visible to short wavelength infrared (VSWIR) spectroscopy, so-called "hyperspectral scanning" by industry, that allows mineral identification and mapping at submillimeter spatial resolution. X-ray computation tomography (XCT) complements these surface imaging techniques by providing three-dimensional density maps of the core interiors, assisting with the recognition of veins, fabrics, and layering, and revealing hitherto unavailable internal imaging of faults and breccias.

With the right instrumentation, these approaches can be fit into onboard workflows. It is critical to recognize up front that they produce very large amounts of data and demand big data analytical approaches that until recently remained in the domains of particle physics or astronomy, but are increasingly required for Earth and environmental sciences. Supervised and unsupervised convoluted neural networks (CNN) can objectively recognize, measure, and quantify the presence of minerals and features, arguably better than the most experienced scientist over a two-month drilling expedition. These approaches should never take the scientists "out of the loop" but will improve the consistency, efficiency, and accuracy of observations once calibrated and tested.

Digital Observations of Oman Drilling Project Core GT2A-120Z2 and Machine Learning Image Interpretations



Example of existing non-destructive core scanning approaches and automated interpretations of digital data for hydrothermally altered gabbros from the lower oceanic crust of the Semail ophiolite, Oman. Note the damage caused to the upper 12 cm of this section (split core optical image) as a result of cutting with a diamond saw blade. *Credits: Optical images from the Oman Drilling Project. Machine learning automated interpretation from Peter Hopkins, Blair Thornton, and Damon Teagle. VSWIR from Rebecca Greenberger and Bethany Ehlmann. XCT analysis from Katsu Michibayashi.*

ML Key

- Background rock
- Altered Gabbro
- Altered olivine
- Epidote
- Clinozoisite
- Zeolite

VSWIR Key

Left panel

- Chlorite
- Chlorite + epidote/clinozoisite
- Epidote/clinozoisite
- Prehnite + epidote/clinozoisite
- Prehnite
- Prehnite + chlorite
- Chlorite + epidote/clinozoisite + prehnite

Right panel

- Zeolite
- Clinopyroxene
- Amphibole