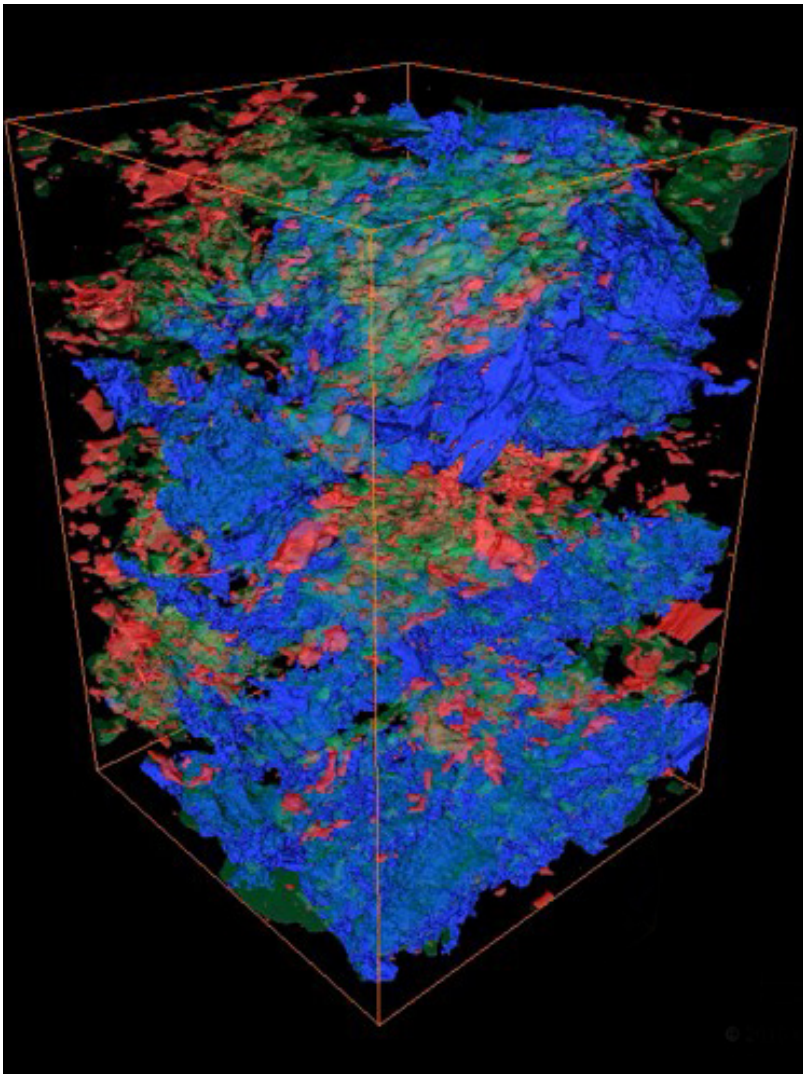
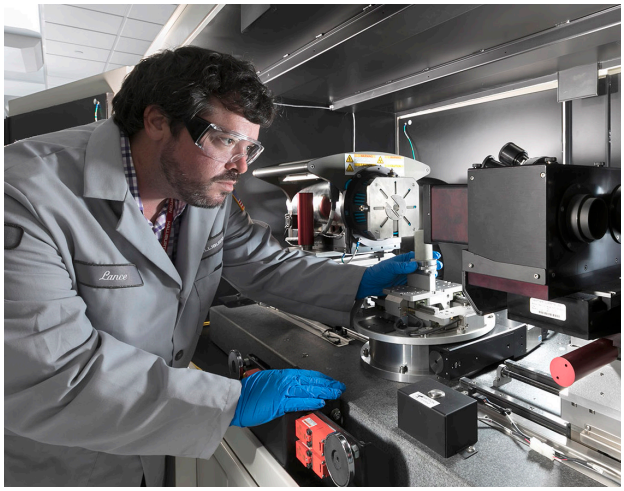




Ingrain Laboratories

INTEGRATED ROCK ANALYSIS
FOR THE OIL AND GAS INDUSTRY

INGRAIN
A HALLIBURTON SERVICE

INGRAIN

We Help Identify and Develop the Most Productive Reservoir by Characterizing Rocks at Pore Level and Upscaling to the Reservoir Level

Ingrain Laboratories

INGRAIN BACKGROUND

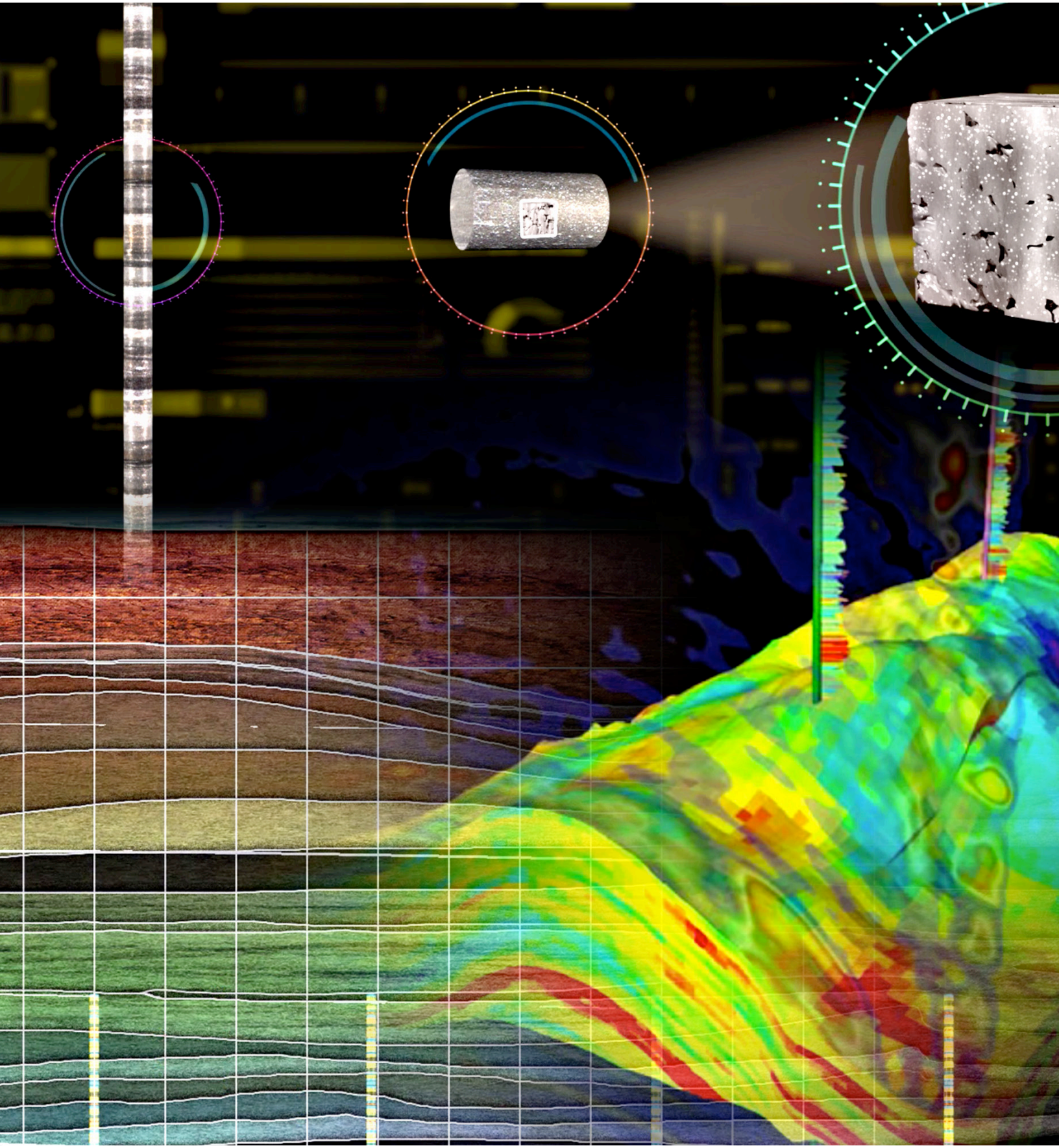
Integrated rock analysis provides the link between downhole measurements and physical properties of the reservoir, including those that control fluid flow. This information can be used to improve well placement, wellbore management, completion design, and recovery rates. Integrated rock analysis leverages pore-scale imaging and computational analysis to link rock properties to laboratory tests, well logs, and production information. Founded in 2007, Ingrain has led the market in developing the field of integrated rock analysis, allowing operators to derive new petrophysical and geological insights for better commercial decision making within completion time frame. Ingrain provides these services worldwide, with laboratories in North America, South America, and the Middle East.

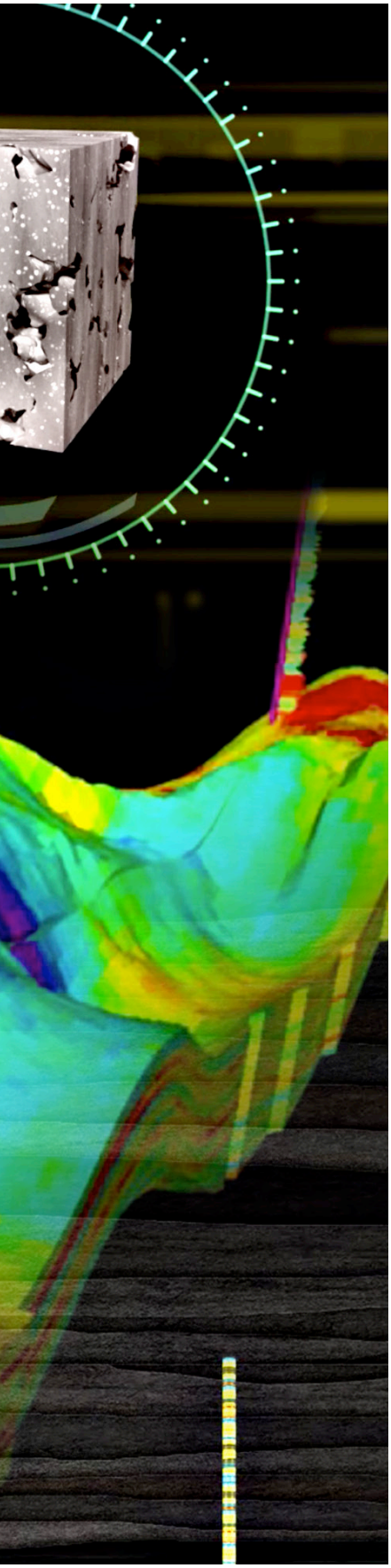
In 2017, Ingrain was acquired by Halliburton and integrated into its Formation Evaluation business lines. This integration enables us to provide improved calibration, verification, and interpretation of petrophysical models by integrating logging data with high-resolution digital rock analysis and physical laboratory tests. Ingrain combines physical measurements and digital core-data to provide interpretations that are used in the exploration and development of hydrocarbon resources around the globe.

TECHNOLOGY DIFFERENCE

Ingrain uses state-of-the-art digital imaging technology combined with conventional physical laboratory measurements. Digital imaging technology available at Ingrain includes medical-grade CT scanners, micro- and nano-CT scanners, and scanning electron microscopes equipped with focused ion-beam ablation capabilities. This technology produces images and data that are used to define rock properties, which can be upscaled from pore to core scale and then integrated with well logs. Over the last 10 years, Ingrain has developed a wide range of proprietary methods to compute reservoir rock properties, such as porosity, permeability, capillary pressure, elastic properties, and electrical properties. These techniques allow the customer to:

- Receive a cost-optimized core analysis road map
- Create a **digital record** of your core using the CoreHD® service, which can be conveniently reviewed from your workstation with LithoVision® software
- **Inspect digital plug analogs** using 3D heterogeneity analysis of lithology and porosity, and avoid non-representative features for core analysis
- Automated facies analysis based on logs, texture, mineralogy, and imaging by using custom machine-learning recipes
- Build **compelling visualizations to describe** complicated geologic processes
- **Characterize porosity** digitally at the appropriate resolution
- Create a framework to upscale essential rock properties from pore scale to reservoir





INGRAIN SOLUTIONS

Petrophysicists – Ingrain builds confidence in well analysis by providing data to validate wireline interpretation in a completion time frame by using integrated core analysis methods. Solutions include effective and total porosity, total organic content, porosity associated with organic matter measurements, and directional permeability.

Geologists – Ingrain provides information including lithology, thin section and computed tomography integration, porosity evaluation, and geometric analysis of pores and grains. This can be used for porosity typing, evaluating diagenesis, and upscaling mineralogy for diagenetic geo-body mapping. High-resolution 3D core sample imaging can reveal complex bedding geometry, stratigraphic surfaces, and can demark fine-scale stacking patterns. This information can be used as input data for an improved static model and reservoir characterization.

Reservoir Engineers – Ingrain provides inputs for full-field simulations. This includes high-resolution characterization of reservoir rock types for total and effective porosity, single and multiphase steady-state relative permeability, capillary pressure, electrical properties, and elastic properties. These solutions can be upscaled to flow units. Multiphase steady-state relative permeability and capillary pressure can have sensitivity analyses on the saturating fluids, contact angle, and wettability.

Geomechanics – Ingrain provides inputs for rock mechanics simulations. This includes high-resolution characterization of bounding layers, including total and effective porosity, permeability, and elastic properties. Whole core analysis can be used to extract fracture density information, and these solutions can be upscaled to vertical formations.

Geochemistry – Ingrain provides source-rock analysis using HAWK™ methodology for organic content, type, and maturity of the rock material. Inorganic geochemistry solutions include isotopic analysis and integration with log data. XRF and XRD analysis permits localized calibration of your formation on the Halliburton GEM™ tool.

Completions Engineering – Ingrain provides inputs for single-well completion options. This includes high-resolution characterization of reservoir rocks types for total and effective porosity, directional permeability, multiphase steady-state relative permeability, capillary pressure, electrical properties, and elastic properties. These solutions can be used for decisions about vertical vs. horizontal completions, sand control, perforation depths, and fracturing design.

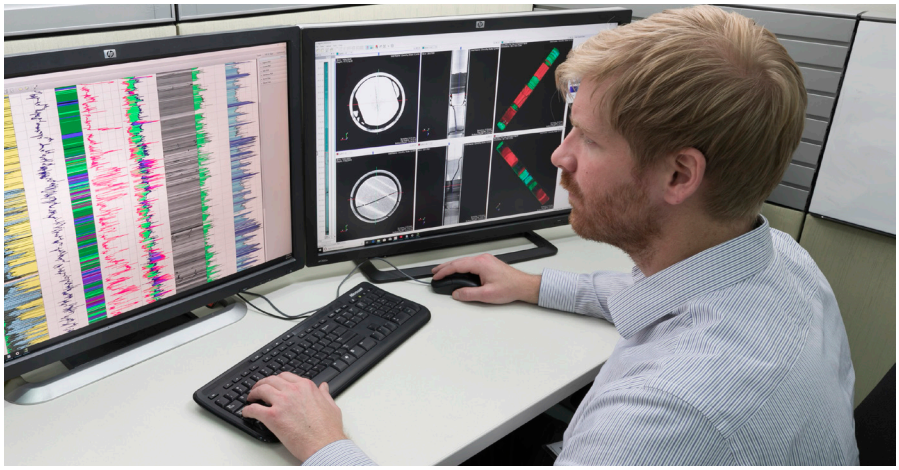
Publications and Patents

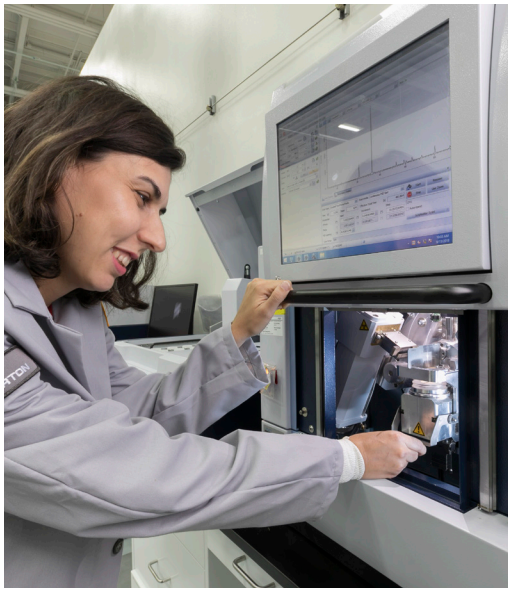
Ingrain currently holds over 20 US patents, and our scientists have authored many publications in a variety of journals and conferences.

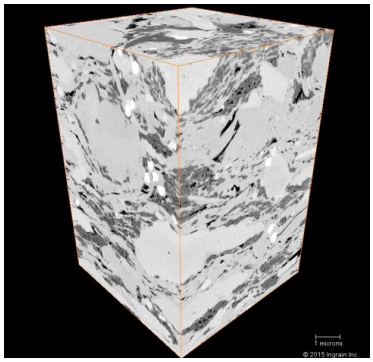
WE ARE INNOVATIVE

Ingrain has pioneered key integrated core analysis techniques with support from laboratories and professionals in North America, South America, and the Middle East. Some of these key innovations include:

- Surface core logging using dual-energy X-ray CT imaging integrated with spectral gamma logging
- Quantifying porosity associated with organic matter in organic shale reservoirs
- Computing directional permeability in shale formations
- Computing relative permeability in shales and complex carbonates
- Upscaling pore-scale properties to whole core and well logs







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Relevant Unconventional Resources

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Uddin, Yasir Naseer, et al. 2017. Quantitative Study of Formation Vertical Permeability in Middle East Thalassinoides Burrowed Carbonate Mudstone. Presented at the SPE Reservoir Characterisation and Simulation Conference and Exhibition, Abu Dhabi, UAE, 8-10 May. SPE-186001-MS. doi:10.2118/186001-ms.

Dernaika, M., Aljallad, O.A., Koronfol, S. et al. 2015. Petrophysical and Fluid Flow Properties of a Tight Carbonate Source Rock Using Digital Rock Physics. *Proc.*, Unconventional Resources Technology Conference (URTeC), Muscat, Oman, 26-28 January. SPE-172959-MS. doi:10.15530/urtec-2015-2154815.

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